HOW TO FLY AN AIRPLANE

PERCIVAL WHITE

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HOW TO FLY AN AIRPLANE

Armstrong Siddeley Motors, Ltd.

"Learning to fly means learning to live in a different sphere, with a new viewpoint, among undreamt-of ideas."

HOW TO FLY AN AIRPLANE

A TEXTBOOK FOR BEGINNERS

BY
PERCIVAL WHITE

HARPER & BROTHERS PUBLISHERS
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1930

HOW TO FLY AN AIRPLANE

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PREFACE

There are, at the present writing, about two hundred and seventy-five schools in the United States devoted to flight instruction. This number is increasing rapidly. Aviation is being popularized at a rate which is completely without precedent. Some indication of this rising popularity may be gained from the statistics of airplane production. In 1926, one thousand planes were built in this country; in 1927, two thousand, and in 1928, five thousand; 1929 almost showed a continuance of this geometric progression.

People are learning to fly by the thousands. The schools at which they learn are those organized solely for that purpose. *How to Fly an Airplane* is intended primarily as a text for use in such schools.

It is also intended for the reader who desires a general knowledge of this most modern art. There are many people who, having no immediate intention of attempting actual flight, feel that a knowledge of aviation is essential in this dynamic world.

This book aims to be elementary. It merely touches on aerodynamics. It contains no technical formulas. It will be of no assistance in the designing of aircraft. It speaks directly to those who wish to handle the controls themselves or who like to imagine themselves doing so. It has a message to those desiring to become licensed pilots, and be masters of the ships in which they fly. Read in conjunction with actual instruction in the air, or in preparation therefor, it will be found helpful. It also aims to be of assistance to those who think that they may later attend a school in which the elements of the theory of flying are taught. By learning the principles set forth here, the time of instruction in the air may be materially shortened. The learner will be able to listen intelligently from the first to the commands which come to him through the earphones of the instruction helmet. Thus, he will gain a sense

of keen anticipation and satisfying confidence which will give him a great advantage over the novice who has no faint idea of what will be expected of him.

Admittedly, this book will never of itself teach anyone how to fly. Nobody expects, merely by reading, to become proficient in swimming, singing, or any other art in which aptitude, skill, and practice are prime essentials. The author's attempt has been to make the book such that a person without previous acquaintance with aviation will, merely by studying the text and examining the profuse illustrations, get a good idea of the principles and scope of flight. Great pains have, therefore, been taken to attain the following objectives:

1. Utility
2. Compactness and simplicity of statement
3. Completeness of essential information
4. A profusion of diagrams, charts, and photographs.

The arrangement of the text is modeled upon the outlines of courses in the leading air schools of the country, it having been based directly upon their curricula. It is, in effect, a composite syllabus of many such courses. The theory and practice of flying have been allowed to run parallel to each other, just as, in aviation schools, ground and flight training are given contemporaneously. The author has attempted to arrange the material so that the chapters may be given out to students as convenient assignments.

Although the purpose of this book is merely to help the student learn to fly, there has been the further effort to promote the cause of safety in flying.

A recent study of public attitudes, made by the Crowell Publishing Company, shows that danger is probably the greatest deterrent to the progress of aviation. As J. H. Doolittle, one of the country's leading pilots, says, "Safety in flight is the principal problem in aviation." The way to make aviation popular is to make it safe. The surest way to make it safe is to train better pilots.

At the end of each chapter a list of readings will be found. These are in books which are readily available. References are given to those portions of these books which are most pertinent.

In addition to the readings, a set of questions for review is appended to each chapter.

Part One of the book is introductory. (Chapter II, which is included in Part One, acquaints the reader with the general procedure of flight training, and gives a bird's-eye view of the methods of maneuvering the plane.) Part Two gives a brief survey of the construction of the plane and of the forces which affect its flight. Part Three describes the method of making the maneuvers which are usually taught during the first six or seven hours of flight instruction. Part Four deals with the more advanced problems of flying. Part Five is devoted to a summary discussion of several subjects calling for special instruction. A glossary and index are appended.

Acknowledgment is made to the following concerns for furnishing excellent illustrations: The Advance Aircraft Company, Troy, Ohio; Alexander Aircraft Company, Colorado Springs, Colorado; American Eagle Aircraft Corporation, Kansas City, Kansas; Bellanca Aircraft Corporation, Wilmington, Delaware; Boeing Air Transport, Inc., Seattle, Washington; Buhl Aircraft Company, Marysville, Michigan; Consolidated Aircraft Corporation, Buffalo, New York; Curtiss Aeroplane & Motor Company, Inc., Garden City, Long Island, New York; Fairchild Airplane Manufacturing Corporation, Farmingdale, New York; Fleet Aircraft, Inc., Buffalo, New York; Fokker Aircraft Corporation of America, Hasbrouck Heights, New Jersey; Ford Motor Company, Dearborn, Michigan; Keystone Aircraft Corporation, Bristol, Pennsylvania; Mahoney-Ryan Aircraft Corporation, Lambert-St. Louis Flying Field, Anglum, St. Louis County, Missouri; Nicholas-Beasley Airplane Company, Inc., Marshall, Missouri; Parks Air College, Inc., St. Louis, Missouri; Pitcairn Aviation, Inc., Philadelphia, Pennsylvania; Pitcairn-Cierva Autogiro Company, Wichita, Kansas; Stinson Aircraft Corporation, Detroit, Michigan; Vickers-Armstrong Limited, New York City; Whittelsey Manufacturing Company, Inc., Bridgeport, Connecticut; The Verville Aircraft Company, Detroit, Michigan; The Fairey Aviation Company, Ltd., Hayes, Middlesex, England; A. V. Roe & Co., Ltd., Newton Heath, Manchester, England; The De Haviland Aircraft Company, Ltd., Stag Lane Aerodrome, Edgware, Middlesex, England; The Black-

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PERCIVAL WHITE

New York City
January, 1930

PART ONE

INTRODUCTION

CHAPTER I. WHY YOU SHOULD LEARN TO FLY

CHAPTER II. THE PROCEDURE OF FLIGHT TRAINING

CHAPTER III. THE QUALIFICATIONS OF A PILOT

The purpose of the Introduction is to give the reader a bird's-eye view of the subject. It will help him to decide what place he is to take in this new sphere, and to visualize the means for reaching that goal.

In the preliminary chapter is given an idea of what flight is like, what recent changes there have been in aviation and what opportunities it now offers, and something about methods of learning to fly. The second chapter explains in considerable detail what this process of learning amounts to, and outlines each of the steps which the student will take in acquiring the art of flight. The third chapter enables the reader to form a judgment as to his chances of becoming a successful pilot.

HOW TO FLY AN AIRPLANE

CHAPTER I

WHY YOU SHOULD LEARN TO FLY

Flying adds a new dimension to life. Learning to fly means learning to live in a different sphere, with a new viewpoint, among undreamt-of ideas. He who acquires the art of flight makes his life over.

Aviation is not a business, not a profession, not a sport. It is not merely any such narrow thing. It is a new form of existence. You are interested in learning to fly, probably for a definite and perhaps a somewhat restricted purpose. But as you begin to grow your wings, to feel them becoming as much a part of you as your more earthly members, you find that your narrower reasons for learning are dropping away, and that you have a broader purpose in accustoming yourself to living in the air. Something within you has changed. It is well to bear all this in mind when you consider taking flight instruction.

What Is Flying Like? Flying gives you a number of sensations, many of which you are familiar with, and it gives them to you all at once. Flying is like diving from a springboard. The airplane is like a sailboat, heeling from side to side as it yaws ahead. It is like a horse, filled with energy and fire, yet always at the command of a cunning master. It is like a bicycle, leaning inward with mathematical precision as it rounds a turn. And it is very like the rise and dip, the dropping and soaring into space, of the roller coaster, but with none of its limitations.

While there is a resemblance between the airplane and a man's more everyday vehicles, flying has an unparalleled element of novelty. The awareness of novelty is apt to be mingled, at the first, with timidity, or at least with nervousness and unwonted

excitement. But do not let these feelings destroy your confidence. Many of the best flyers experienced them at first. A little experience will accustom you to this antic of hurtling through space, and being tossed about a bit in the process.

Of course, there is bound to be a certain amount of mystery connected with the air, as a medium of travel. To the man on the street, the atmosphere is mere vacuity, a sort of ether through which the clouds slide silently, as though they were projected from a moving picture camera. Scientists tell us that deep-sea fish are not even cognizant of the existence of water: many people seem as little aware of the fluid in which they live.

But learning to fly brings you the conception of the air as a tangible, almost a solid, substance. Flying gives meaning to the impact of storm against storm, of cloud against cloud. To the aviator, as to the windjammer of a former generation, the air is substantial, alive with motion and power. To the aviator, the air is a splendid right of way. To him, a railway, with its accurately surveyed route, its careful ballasting, and its precise rails, is a roadbed less perfect than his path through the sky.

The Opportunities Before the Aviator. In the aviation industry itself, there are great opportunities for employment and for individual enterprise. All of a sudden, aviation has come into its own. Capital, once so shy, has gone to the extreme of prodigality. Millions are being invested in aviation. Such investments call for earnings. Earnings, to the manufacturer, call for quantity production. The result is that the production of planes is much more rapid than is the production of pilots. The United States would not find it a serious problem to turn out one first-class airplane a minute; but finished pilots cannot be produced so quickly. The demand far exceeds the supply. And only time can create a sufficient supply—time spent in hard, conscientious, and unremitting attention to this most skillful of pursuits.

The man who expects to enter aviation as a business, even though as a mere executive, has a far better chance of success if he knows how to fly. One would not expect a great deal of the president of an automobile company who could not drive a car.

To the young man wishing to enter aviation as a business, there is great advantage in becoming an expert pilot. It is a good

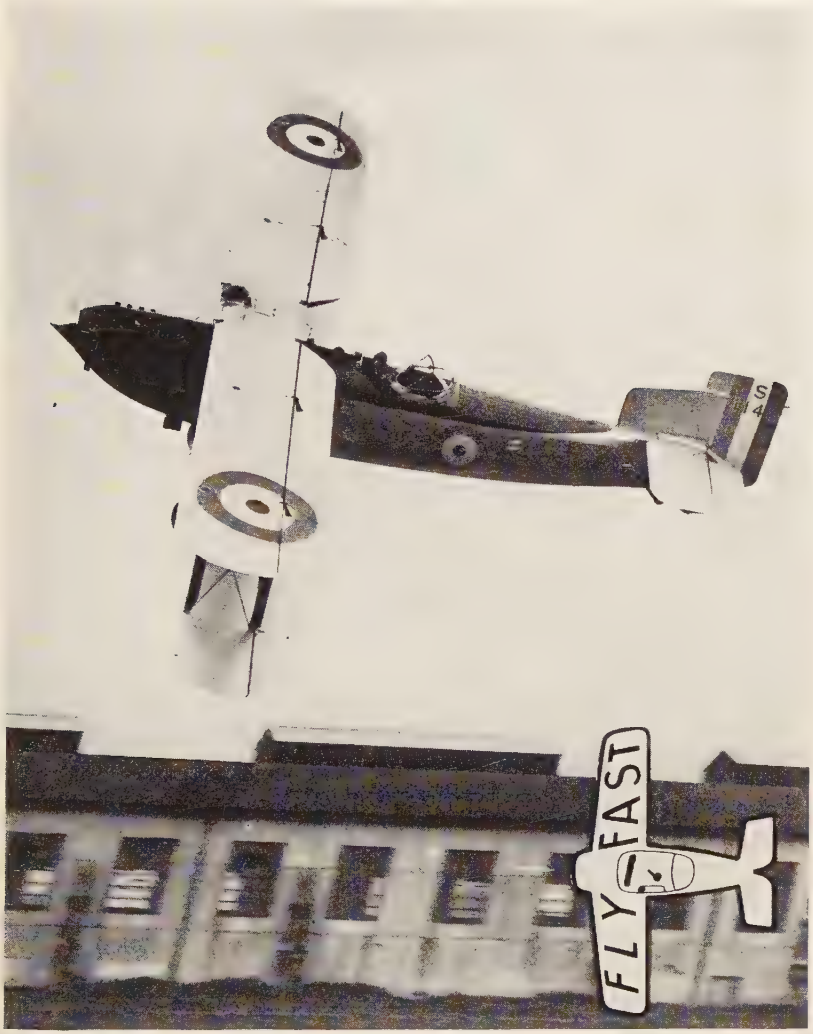


Fig. 1. A Very Sharp Turn

This turn is very spectacular when it is executed so near the ground. Nevertheless, it violates one of the first rules of flying, that no "acrobatics" should be attempted until a safe altitude has been reached. (The "control diagram" in the lower right-hand corner is explained in Chapter II.)

way to get started in this growing industry. There will be, for years to come, an opportunity for skillful, judicious, and trustworthy pilots. In fact, there will probably always be an undersupply of them. To the older man, flight instruction offers an opportunity to gain that acquaintance with the practical problems of the subject which is essential to proficiency in all phases of the aviation industry.

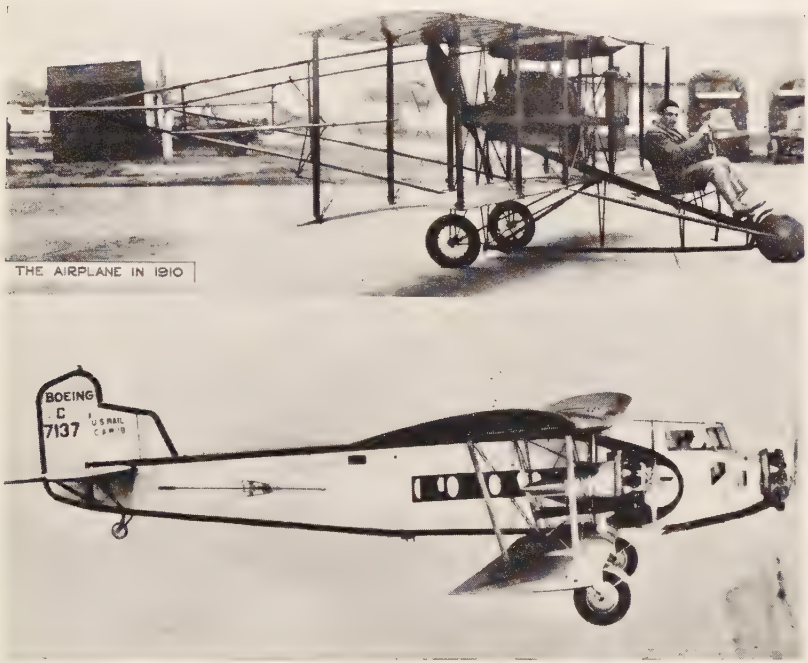
There is one lucrative purpose to which flying should not be put: that is to gain personal publicity. Many people fly merely to add to their notoriety. These are the ones who attempt reckless feats in order to put themselves in the headlines of the newspapers. It is these daredevils who create the general impression that flight is foolhardy and more dangerous than the antics of circus performers. In order to become as widely used as automobile transportation, the airplane must inspire the confidence of everybody. Such confidence is certain to be forfeited, nevertheless, as long as aviation is brought to the public mind through the behavior of those who are desirous of establishing fame in order that they may capitalize it. Such a reckless stunt is shown in Figure 1, which is a "reverse-control" turn executed twenty feet above the ground.

Sane flying undoubtedly is comparatively free from risk. By carefully studying the principles of flight, and by practicing them in the air until control over the plane is complete, pilots will incur the minimum of danger.

Advantages of Aviation to the Mass of People. Outside of the commercial world, there is the mass of people who desire to learn to fly for the love of it. Aviation is replete with thrills. It has all the elements for Twentieth Century popularity. It is destined to have a wide vogue among sportsmen, as soon as it is possible to purchase ships at a reasonable price. Flying is the most exhilarating of sports. Although it is fairly easy to learn the rudiments, there is opportunity for developing an extreme degree of skill, especially when engaged in "acrobatics."

Flying is splendid discipline; discipline not of the mind alone, nor of the body alone, but requiring the nicest coördination between the two. Perhaps there is no pursuit better than flying for the development of courage, self-reliance, and those other

attributes for which, especially in the past, this country has been renowned. Incidentally, after having learned to fly, it is quite a satisfaction to feel that one has overcome his natural fear of the air.



Boeing Air Transport System

FIG. 2. THE IMPROVEMENT IN AIRPLANE CONSTRUCTION DURING THE LAST TWENTY YEARS

The type of airplane shown at the top of this illustration caused quite a sensation when it was first built in 1910. The "pusher" propeller can be seen, located behind the wings. The plane was built of wood and linen, weighed less than a thousand pounds, and had a maximum speed of less than fifty miles an hour.

Progress in the Construction of Airplanes. Before flight came to merit the confidence which can now be placed in it, many steps have had to be taken by experts in aviation and in aerodynamics. Figure 2 compares the airplane of twenty years ago with the modern passenger transport.

It is only a quarter of a century since the Wright Brothers made their first flight. It was as late as 1911 that Glenn H. Curtiss demonstrated his hydroaeroplane. During those early years of aviation, development was empirical. Success or failure was determined by actual tests in the air, usually to the great personal danger of the pioneer pilot. There were no great laboratories for the study of aerodynamics, such as exist today at the Massachusetts Institute of Technology and elsewhere. Aviation, in its early days, had difficulties to encounter far beyond those of the automobile or the radio. Most detrimental to its progress was public indifference. The future of the industry was in the hands of a few zealots, who, in spite of almost insuperable obstacles, persisted with their experiments.

But when the World War broke out, the airplane became all-important as a military machine. The result was that in four years and two months of war, aviation made tremendous strides forward, not only in technique, but also in popular appeal. After the war, experimentation was needed before design was sufficiently perfected for commercial advancement. Such progress, however, was then possible, because of laboratories erected during the war, the experts who had studied aerodynamics and aviation in the technical schools during that period, and the flyers who had distinguished themselves, and were now available to the newly found industry. The consequence was that the airplane passed out of the empirical stage into that of the technically designed and scientifically manufactured product. Before an airplane now takes the air, it is tested so carefully in the laboratory by means of scale models, and the effect of all the controlling factors is so carefully computed, that the speed and lift of the plane are known in advance.

Today, the progress of aviation is scientific, not merely the result of trial and error. There are many difficulties to overcome, but there is a definite goal to work towards, and there is little doubt that, before many years, aviation will be one of the world's great industries.

Aviation Schools. There are now schools in practically every part of the country which give the student a carefully

planned schedule of instruction. The Air Commerce Regulations classify these schools under three headings:

1. Flying schools, which give practical instruction in the air.

2. Ground schools, which give classes in such subjects as the history of aviation, aerodynamics, design, engines, meteorology, navigation, and rigging.

3. Ground and flying schools which combine theoretical and practical instruction.

The flying school fits a student to be a pilot, but a certain amount of ground instruction is also required. The student should know something of airplane construction, maintenance, and care. Flying schools are licensed by the Secretary of Commerce only after examination as to the airworthiness of the equipment and the competency of the instructors.

A few years ago, learning to fly was rather a difficult task. According to the Curtiss system, as it was then called, the student had to learn virtually by himself. This method was used during the war when many of the planes would carry but one man. The student started out alone, learning to "taxy." Then he was permitted to use a little more power until he could hop from one end of the field to the other. Day by day he was allowed to go a little higher, until he was in the air and doing all sorts of maneuvers, including acrobatics and precision landings. The method, unfortunately, was characterized by numerous crashes while learning, although few of them were serious, since the student was not allowed to get far enough off the ground to do himself much harm until he was competent to handle the plane. The French developed a somewhat similar method of training called the Penguin or "rouleur" system.

The modern method is one of dual instruction, formerly called the Wright system. The instructor begins by going up in the air each time with the student until he is at last able to fly alone with safety. Either the pilot or the student can guide the plane, by this system, so that, at any time, control may be taken over by one from the other.

Choosing a School. There is a great deal of variation in the schools offering ground and flight instruction. Some are small,

with only a plane or two for equipment; others are large, with hangars and "ships" in abundance. Some schools charge a considerable sum for tuition; others are more reasonable; some schools specialize on the technical end of the training; others make it their primary endeavor to turn out a pilot who can fly as soon as possible. Thus it will depend a great deal upon the individual as to what school he chooses.

Many schools offer ground training and this is given in conjunction with a flight course of ten hours' dual instruction. Elementary instruction of this type costs from $200 to $400. Supplementary training is furnished at an additional fee, and this advanced instruction is usually necessary in order to enable the pilot to pass his federal pilot's license test.

Occasionally a school allows the student to obtain his ground training by letting him work on equipment, both planes and motors. For a transport pilot such mechanical experience is required; but for an ordinary private pilot it is perhaps not worth while to spend a great deal of time on this. If mechanical instruction is taken, it is usually at the same time as the flight instruction.

There was at one time a belief that an expert pilot could not be trained in less than a year. As time goes on, the period of training is becoming shorter and shorter. The average student can learn how to handle an airplane under modern conditions of instruction, including all the advanced flying which he will be required to make in the ordinary flying of his plane, after 30 or 40 hours of flying. This, of course, does not include cross-country flights or the maneuvers commonly associated with advanced military training.

On the other hand, instruction should never be too hurried. Lessons should not be too long but should come at regular and rather frequent periods. One who qualifies for a transport pilot's license will find his instruction spread out over a period of months, but the bulk of his later training will be in the line of added experience rather than in learning any new principles. The ordinary course of instruction leading to a private license will cover from 4 to 6 weeks, including the ground course.

Contrary to general conceptions, flight training is fairly safe

physically, because great pains are taken to provide every precaution. The planes used are of types which are as foolproof as can be made; the pilots employed as trainers do not take risks with the students, in fact, the risk involved in learning at a good school is negligible. It is often said that driving an automobile along a crowded street is as dangerous as flying. This may seem exaggerated, in view of the publicity given to airplane "crack-ups," but, as a general statement, it is approximately true.

Types of Airplanes. There are several types of airplanes in common use. The first distinction is between the land plane and the seaplane. The former must have solid ground to land on, while the latter must find open water. In addition, there is the so-called amphibian plane, which is capable of landing either on water or on land.

A second distinction between types of planes is the number of wing surfaces. The monoplane is undoubtedly rising in favor, but there are many biplanes, and these are the ones commonly used for training purposes. Planes with three sets of wing surfaces, or triplanes, have occasionally been used in the past.

A third distinction relates to the airplane's purpose, as for commercial use, for military use, or for private pleasure.

There are many special types of airplanes which fall outside these classifications, since they have not come into common use. Among these is the ornithopter, a machine with flapping wings. This device has never been successful. Again, attempts have been made to construct a heavier-than-air machine capable of descending from any altitude along a vertical course. Such a device would obviate most of the present difficulties in landing. It is on this principle that the helicopter was devised. The helicopter has a propeller which revolves in a horizontal plane above the fuselage, and which has sufficient lifting power to replace the wings. The helicopter presents many aerodynamic difficulties, and has, therefore, never been perfected. A machine which has actually been built to make landings in a course approximately perpendicular to the earth's surface is the "Autogiro." This, besides having an ordinary engine, propeller, and short wings, is equipped with a sort of windmill revolved in a horizontal plane by the force of

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the air against it, so that the plane is able to drop and to ascend in an almost vertical course. (See Figure 3.)

Land Planes. There are a great many different types of land planes, varying in size, capacity, purpose, and number of engines and wing surfaces. Each type has been developed to fill

FIG. 3. THE AUTOGIRO

This machine, though not strictly speaking a helicopter, works somewhat on the same principle. By virtue of the horizontal "windmill," or airscrew, the machine is enabled to ascend or descend in a substantially vertical direction.

some special need. The emphasis today is on the plane built for commercial purposes, although great development has also been made in planes built for military use, of which Figure 4 is an example. Today every type of ship from the tiny, folding-wing sport plane to the high-powered transport passenger plane can be purchased. (See Figure 5.)

Official Photograph, U. S. Navy

FIG. 4. A MILITARY PLANE

This powerful weapon is a torpedo and bombing plane. Although used by the Navy, it is a land plane of more or less conventional biplane design. There has been great advance in the design of fighting planes since the War.

Boeing Air Transport System

FIG. 5. A COMMERCIAL PLANE

This ship flies both passengers and mail. It is shown above the Ruby mountains of Nevada. In this kind of flying, great dependence is upon the engine.

Monoplanes, or planes with a single wing surface, are the most efficient type of plane for many purposes. Of the relative advantages of monoplanes and biplanes, it is generally true that the monoplane is better for carrying weight, and perhaps cheaper to build, while the biplane is structurally stronger and easier to handle. Therefore, monoplanes are most often used for commercial purposes, and biplanes for instruction. Incidentally, the pas-

Fig. 6. Cabin Plane with Cockpit

In addition to the enclosed cabin for passengers there is a cockpit for the pilot. This gives him a position where he can see well.

senger's ability to see is better in most monoplanes. This is a consideration of some importance.

Monoplanes may be either high-winged or low-winged. Figure 6 shows the cabin monoplane used by the noted pilot Captain Hawks in making a record transcontinental west to east non-stop speed flight. Enclosed cockpits allow greater comfort for the pilot, but make it more difficult to see and render his position more hazardous in the event of an accident.

Figure 7 shows an open biplane of conventional design, with a double open cockpit. Figure 8 shows a much rarer design—a cabin biplane.

There are, of course, a great many planes designed for special purposes, such as high-speed planes for racing, long-range air-

"Flight" Photograph

FIG. 7. AN OPEN BIPLANE (D. H. Moth)

This photograph is one of Captain and Mrs. Geoffrey De Haviland over England in their record-breaking altitude flight of 21,000 feet.

planes for distance flights, and machines designed to reach high altitudes. Military pursuit planes are designed to perform all kinds of acrobatics which might prove essential in warfare.

The Seaplane. A seaplane is a type of airplane which is built essentially to take off and land on the water. Seaplanes are of two general types: the float seaplane and the flying boat. The

float seaplane lands on pontoons, or floats. Sometimes a single float is used; more often, there are two. The fuselage of the float seaplane is perched well above the surface of the water, as in Figure 9. When this plane is taxying at low speed, the floats plow through the water much as a boat does. As it attains greater

Flight

FIG. 8. A CABIN BIPLANE

Cabin biplanes are uncommon in the United States. This is a British military machine. It is a Handley-Page Troop Carrier. It is powered by two air-cooled Bristol Jupiter geared engines. Notice the landing gear.

speed, the floats become hydroplanes and the resistance of the water lessens, due to the breaking up of the surface tension of the water by the step of the hydroplane. A seaplane is designed so that it will "weathercock"; that is, the plane tends to ride head into the wind when it is on the surface of the water. Much difficulty was experienced in early days in getting enough power from the seaplane motor to enable the floats to come out of the

U. S. Navy

FIG. 9. FLOAT SEAPLANE

This beautiful ship is of the two-float type. It is a naval torpedo and bombing machine. It is flying over Panama.

Fig. 10. A Flying Boat

This is a high-performance ship, designed for military purposes. It is the Blackburn "Iris" boat, powered with three Rolls-Royce engines. It is shown at the instant before landing.

water into the hydroplaning stage, this being necessary to gain enough speed to enable the plane to take off.

The engine on a seaplane is carried high above the water because the propeller must not be struck by waves or spray. In the flying boat shown in Figure 10 the engines are mounted between the wings, where they are well out of the water. The flying boat

U. S. Navy

FIG. 11. NAVY PATROL BOAT

By comparing this with the photographs of land planes, some considerable differences of construction will appear. The engine cannot be located in the nose of a flying boat. The whole arrangement of the component units is different.

differs from the float seaplane in that the fuselage of the plane forms the main float, with small pontoons under each wing tip, preventing the wings from getting into the water.

Float seaplanes and flying boats may be either monoplanes or biplanes. Figure 11 illustrates a navy patrol boat of the biplane type. The engines here are mounted above the lower wing.

The amphibian plane is meant to land on either land or water.

When a landing is to be made on dry ground, a set of wheels is let down from the sides of the fuselage. Figure 12 shows a twin-engined amphibian passenger transport, which can alight or take off from the land or water. In acquiring its dual character the

Pratt & Whitney

FIG. 12. AN AMPHIBIAN PASSENGER TRANSPORT (SIKORSKY)

The pontoons can be seen beneath the lower wings. When the ship is to land on the ground, wheels may be let down from the sides of the fuselage.

amphibian loses some of the speed and other features of the more specialized types.

* * *

Anyone who goes to an airport or a flight school to watch the maneuvers of ships in the air, and to inspect the various types of planes on the ground, will be stirred with the desire to fly.

"Casey" Jones, the famous instructor pilot, has issued this statement:

"To You, young man of pioneering spirit, ambitious for your future, and possessing a willingness for hard work, aviation offers unlimited opportunities. Learn to fly, and some day, above all material reward the future holds, will come that satisfaction that only those can know who, in the accomplishment of this new art, have said, 'I have just soloed.'"

SUGGESTIONS FOR READING PREVIOUS TO TRAINING

LINDBERGH, CHARLES A., *We*, chap. I. Putnam.
JONES, BYRON Q., *Practical Flying*, chaps. I, II, III. Ronald.
GOULD, BRUCE, *Sky Larking*, chaps. I, II. Horace Liveright.
HINTON, WALTER, *Opportunities in Aviation*, chap. I. Norton.

QUESTIONS FOR REVIEW

1. What, to your mind, stand out as the epochal events in the history of aviation?
2. Whom do you consider the ten outstanding figures in the development of aviation?
3. Enumerate the reasons in favor of your learning to fly. What are the reasons against your learning?
4. What appear to be the best opportunities for trained pilots, in your locality?
5. What airplane accidents are you familiar with? How might they have been prevented?
6. What developments do you expect to see in the business side of aviation during the next ten years?
7. What subjects have you studied and what training have you had which you think will be of the greatest value in learning to fly? State your reasons.
8. Interview any flyers you know as to the most important things to learn, during your early training.
9. Examine recent aviation periodicals and their descriptions of the latest types of airplanes. Are any trends in designs indicated?
10. What value, if any, do you expect to receive from a book on flying? How would you expect to make use of it?

CHAPTER II

THE PROCEDURE OF FLIGHT TRAINING

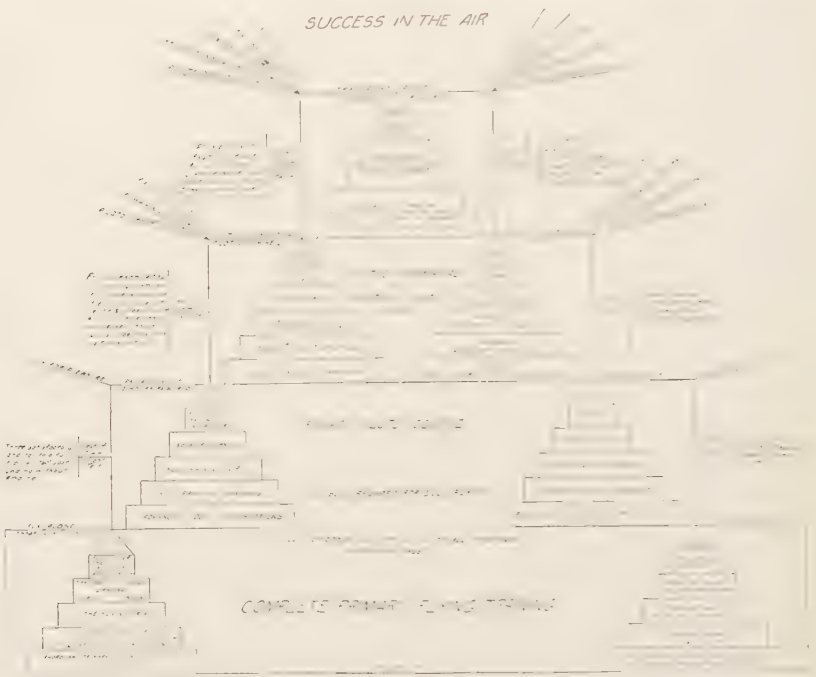
Before you start to fly, you should become as well acquainted as possible with flying technique. You should know something of the process of instruction, and also the different steps of such instruction. It is the aim of this chapter to outline the process of training as a whole, and to explain the terminology of aviation in so far as a beginner will need to know it. Figure 13 is an interesting attempt to outline in graphic form what flying training includes, not only for private pilots, but also for limited commercial and for transport pilots.

While this book does not attempt to cover airplane design, airplane construction, rigging, ground training, and similar subjects not connected with the actual operation of an airplane, this chapter gives a brief résumé of such terms and some of the information you should have. It also takes up the steps in preliminary flying, and carries it on through advanced instruction and acrobatics. It is a summary of the air work described in the rest of the book.

The Instructor. A great deal depends upon the instructor who gives you your flight training. As in all teaching, mere knowledge of one's subject is not sufficient. The instructor must not only be an expert pilot, but he must be able to impart his information to the student. He must, furthermore, be possessed of sufficient patience to allow him to obtain the confidence of the student and to understand the student's reaction to flying. He must not only diagnose and be able to correct errors, but he should be able to determine why the errors were made and point out the reason, whether through nervousness, lack of judgment, failure to understand the principle of the maneuver, or other defect.

The Air Commerce Regulations prescribe rigid conditions for

instructor-pilots. Each instructor must be a transport pilot with a rating from the Department of Commerce, and must have passed the examination with a grade of at least 70 per cent. If he serves as flying instructor for 100 hours in an approved school for dual



Capitol Airways, Inc.

FIG. 13. STEPS IN FLIGHT TRAINING

This chart shows the various steps in a pilot's training. The pyramids at the bottom of the graph represent the instruction which must be given before the novice may fly alone in a plane. The second set of pyramids shows the knowledge and ability of which a student must give proof before he can obtain a private license. The next two pyramids indicate the requirements for a limited commercial license. At the peak of the graph are the qualifications for a transport pilot.

instruction, his rating is renewed. He is not allowed to give more than 6 hours' dual instruction a day, or more than 6 days a week, by the provisions of the Department of Commerce, and for any violation of regulations, carelessness or inattention, or demon-

strated incompetency, his license may be immediately suspended or revoked.

A ground instructor must also hold a rating from the Department of Commerce. This is based upon ability to instruct in one or more ground school subjects. This rating may be suspended or revoked for violation of provisions of the Air Commerce Act of 1926, the Air Commerce Regulations, or carelessness, incompetency, or other serious breach.

The flight instructor should have had a minimum of 500 hours in the air, so that recovery of control from any position in the air has become almost automatic with him.

Preliminary Knowledge. Every student should have some knowledge of aviation before learning to fly. Learning to fly is not so simple as learning to drive an automobile, though the two have much in common. A person beginning to drive a car must have instruction from some other person, but he must also have a knowledge of what the various controls are used for, and how they are used. He must know the traffic regulations, and he must learn how important it is to coördinate the action of hand and brain. The same holds true of the student in flying. He must know how and why the plane stays up in the air; he must know the air traffic regulations; he must know the parts of the plane. He cannot learn these things while flying because communication is difficult then, since the ordinary system of communication between pilot and student allows the pilot to talk and the student to listen, but not vice versa. The student will also understand much better the various steps in flying procedure if he has studied in advance the principles underlying them. He should understand what the pilot is trying to show him, and this preliminary knowledge will make it much easier for him to anticipate the pilot's instructions. It is the purpose of this book to supply this expository material, so that the student will be able to absorb actual flight instruction more readily and with greater speed. He will also be able to save much expensive time in the air by learning what mistakes to guard against.

The training of students, which once was subject to little regulation, has now become standardized to a great degree. The work has been organized so that there is little risk of the student injur-

ing himself, so long as he follows the instructor's commands. One of the most important parts of this training is the familiarization of the student with parts of the plane and their functions, so that when he actually goes up in the air, he knows what he is doing.

Ground Training. A student can learn a great deal by getting into the cockpit while the ship is on the ground and getting an idea of how the controls work. He will become accustomed to the angle at which the plane sits on the ground. He can be drilled in movements of the stick, rudder-bar, and throttle. This, however, is only a small part of the ground training.

Before he is ready for dual instruction he should know something of the principles of flight, of aircraft construction, of engine construction and operation, and something also of the way winds and weather affect plane operation, or meteorology. Such training should not be theoretical alone. He should familiarize himself with the maintenance and repair of planes and motors by actually working on them, although the sport pilot may perhaps give less attention to this than one who is going into aviation commercially. Some schools require student pilots to do this repair work on engines under skilled instruction, on the theory that this is the best way to become acquainted with the plane and how it works. Much of this latter training may be carried on during the period of dual flight instruction, the beneficial effects of one helping out the other.

General Knowledge. While a thorough knowledge of the history and development of aviation is not essential to learning to fly, it is highly desirable from the point of view of general interest. The student should know about the early experiments carried on before the conquest of the air was possible, how the various types of planes were evolved, what their advantages and disadvantages are, and the development of the airplane along military, commercial, and sport lines.

Aviation nomenclature is another picturesque part of the student's equipment. Aviation has developed a terminology peculiarly its own. In addition to technical terms, pilots have developed a number of slang expressions which most novices use with a good deal of satisfaction. These expressions serve a purpose as useful

to the aviator as the lingo of the forecastle does to the sailor. (See Glossary.)

Aerodynamics is a highly technical subject, treating of the effect of force as applied to the atmosphere. It is not easy to understand why a plane does this or that; but the student should at least be able to explain what brings about a ship's flying, or gliding, or stalling. He should know why the wing surfaces are curved or cambered instead of being flat, and something also of the effect of power in relation to the angle at which the wings face the air, of the force of gravity as applied to an aircraft, why a plane maintains its equilibrium, and the principles which underlie the operation of the various controls. He should understand the difference between air speed and ground speed. And particularly, he should appreciate why it is essential to fly fast.

Airplane Structure. It is important to know something of how the airplane is made, and of the parts which enter into its construction. The chief wear and tear on airplanes comes in landing, taxying, and taking off. The vibration of the motor sometimes causes crystallization of metal members, and consequent breakage, but this is comparatively rare. There is also some deterioration from weathering, but this is a minor matter. The materials of which the plane is constructed are relatively simple. The framework of the fuselage, or body, is usually made of steel tubing, wood being more dangerous to the occupants in case of a crash. (See Figure 14, illustrating framework of steel fuselage.) Over this framework is stretched a covering of fabric, treated with "dope" (as cellulose acetate or nitrate is known). The action of the dope is to stretch the fabric, besides making it waterproof and preventing the air from passing through. Sometimes the fuselage is sheathed with wood veneer or some metal, such as duralumin.

Underneath the fuselage is the landing gear, consisting (in land planes) of a pair of wheels, a shock-absorbing mechanism, and the necessary rigid supporting members. Underneath the tail of the plane is the so-called tail skid. This supports the tail when the ship is at rest on the ground and allows it to slide along when taxying. In landing, the tail skid is useful for its braking effects. There are various methods employed to absorb the shock of

landing. The rubber tires, of course, are of some help, but in addition there are shock absorbers made of rubber, and others, which, by the use of air or a liquid or springs, or various combinations, take up and damp the shock. (See Figure 15.) Large planes are often equipped with a small wheel under the tail, instead of the conventional skid, to avoid tearing up the ground, and to facilitate taxying.

Wing construction has been fairly well standardized, whether it is of wood or metal. Ribs are frequently made of plywood, or

Berliner-Joyce Aircraft Corporation

FIG. 14. FUSELAGE CONSTRUCTION

This illustration shows the framework of the fuselage (body). Formerly, such framework was built of wood, but this was found to shatter very easily if the plane crashed. Now, the frame is usually made of steel tubing welded together. This framework is then covered with a fabric or with metal. In the illustration the fin to which the rudder will be attached, the openings for two cockpits, and the gasoline tank may also be seen.

thin strips of wood glued together with the grain running in different directions. The ribs are fastened to spars or beams which run lengthwise of the wing. Struts, steel rods, and wires are used to truss the whole wing to withstand the complicated loads which it is called upon to bear. In a monoplane, there is sometimes no external wing bracing, but more frequently there are struts which brace the wing to the fuselage. Biplanes always employ a system of trussing. The vertical struts (compression members) are of wood or steel tubing, while the diagonals (tension members) are wires, sometimes of streamline shape.

FIG. 15. LANDING GEAR OF A LAND PLANE

This plane is equipped with the usual type of landing gear, consisting of wheels with their rigid supporting members, and a tail skid at the end of the fuselage, which may be seen in the illustration below the plane's left wing.

This photograph is of an Army Pursuit Plane, which has a maximum speed of 185 miles when carrying a full military load.

The framework which carries the engine is known as the engine mount. In land planes, the engine is usually located in the nose, and is insulated by a firewall from the fuel tank and cockpit. When there is more than one motor, or in seaplanes and boats, the engines are often mounted on the wing structure.

The tail group of the plane is made up of vertical and horizontal surfaces. (See Figure 16.) The vertical surfaces are the fin, which is fixed, and the rudder, which is movable. The

Berliner-Joyce Aircraft Corporation

FIG. 16. TAIL GROUP

This high-winged monoplane has been photographed in such a position that the tail group, or empanage, is easily seen. The tail group consists of vertical and horizontal surfaces which act against the air to control the movements of the plane. The vertical, somewhat circular surface is made up of the rudder, which swings from side to side, and the fin, which is stationary and to which the rudder is hinged. Projecting from the fuselage, at either side of the rudder, are two horizontal surfaces. Each of these surfaces consists of a stabilizer, which is on this airplane the smaller section of the surface, and an elevator.

horizontal surfaces are the stabilizers and the elevators, both of which are movable, though the elevators are the more mobile of the two.

Rudder-Bar and Stick. The student begins work at the outset with the controls. Then he operates by means of the rudder-bar or foot-bar, and the "stick" or "wheel." The foot-bar which controls the rudder is used on all planes, although sometimes it is in the form of pedals which require less width and are easily adjusted to the individual pilot. From the foot-bar cables are

connected to "horns" or projections on each side of the rudder. Pressure with the right foot (right rudder) pulls the rudder towards the right. Right rudder turns to the right.

The "stick," or "joy stick," is hinged so as to have a universal motion. It operates both the elevators and the ailerons. When pushed sidewise it moves the ailerons; when pushed back and frontwards it moves the elevators. The elevators are horizontal airfoils positioned at the rear of the stabilizer, which govern the up-and-down movement of the plane. These are operated also by means of horns, which are actuated by cables leading from the stick. Pushing the stick forward depresses the elevators and makes the plane's nose point downward. Pulling it back has the contrary effect.

Since the movements of the controls must be precise, and since any faulty action may be disastrous, the student must learn as soon as possible to correct his mistakes. In order to aid him in the acquiring of this familiarity, many of the illustrations in this book are supplemented by a plan of the rudder-bar, stick, and throttle. This plan shows how the controls were used in order to effect the maneuver which is shown in the diagram or photograph. Figure 17 is an example of the diagram which would accompany the picture of a plane in a right turn.

There are cables leading from the stick to *horns* on the ailerons, fastened in such a way that a movement of the stick to the right rolls the airplane downward to the right. That is, if the stick is moved to the right, the right aileron goes up and the left one goes down, thus producing the desired bank to the right. In large airplanes, where a stick is not sufficiently powerful to operate the ailerons, a wheel is provided for that purpose.

The Engine. The engine is controlled by a hand throttle, located at one side of the cockpit, usually at the left. Since there is no clutch or transmission (as in an automobile), any movement of the hand throttle is instantly reflected in the air speed.

Airplane engines are normally of the four-cycle type. They may be either air- or water-cooled, and are designed to give the maximum horsepower per pound of weight. Water-cooled engines are heavier, but have the advantage that they can be neatly streamlined.

A good ground school pays much attention to the engine, starting with such ordinary operations as instruction in ignition systems, carburetion, lubrication, trouble-shooting, valve adjustment, and the installation in the airplane. The safety of the pilot is so dependent upon the performance of his engine that every detail connected with its operation is of paramount importance

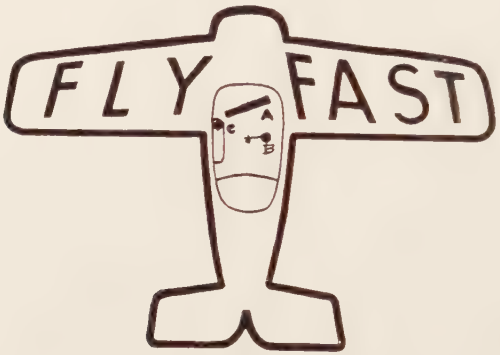


FIG. 17. OPERATION OF THE CONTROLS

Diagrams like this are appended to many of the photographs in this book. The diagram shows how the stick, rudder-bar, and throttle will look just as the ship reaches the particular position illustrated in the photograph. (These diagrams do not in every case agree with the control surfaces as they actually appear in the photograph, since the latter may have been moved at this moment, due, for instance, to a "bump.")

The black bar is the rudder-bar. The black spot in front of the pilot's seat represents the *top* of the stick, while the line running from this point to the center of the cockpit floor represents the stick itself. The throttle is shown at the left. When in the forward position, it is open; when pulled back, it is closed.

For a complete discussion of controls, see the chapter on that subject.

Instruments. Ordinary flying does not require many instruments. Some instructors believe a student should learn to fly without them entirely, so that he can tell by the sound of the engine and by general observation whether every condition is favorable. Instruments are of great aid, nevertheless, in minimizing the effect of poor judgment and guesswork, and, even though a pilot may be able to judge his speed within a few miles by the "feel"

of the plane, it is well for him to check his opinion by means of actual measurement.

Instruments are usually divided into three classes: first, those dealing with the power plant; second, those relating to stability or flight; and third, those having to do with navigation. The power plant instruments record the condition and operation of the engine. The tachometer indicates the number of revolutions per minute which the engine is making; the oil pressure gauges indicate the pressure of the oil; the thermometers show how hot the parts of the power plant are; the gasoline level gauge shows how much fuel remains in the tank.

The instruments for stability and navigation are particularly important for the commercial and transport pilot, and even the private pilot will need certain of them. The altimeter, for example, shows the height at which the plane is flying. Air speed indicators enable one to calculate how much time will be taken between landing fields in cross-country flying. Compasses show the direction taken by the plane. Ordinary magnetic compasses are sometimes used, but the so-called earth inductor compass is somewhat more satisfactory. There are instruments to help one to prevent yawing, when in straight flight, and to show the correct angle of bank when making a turn. Indicators are also available which show the rate of the plane's climb, or its descent. Even more complicated instruments have also been developed, such as those which, by calculating the drift, wind speed, wind direction, and ground speed, show the course which must be held in order to reach a given point.

There are other instruments sometimes employed in planes. The barograph, for example, is an altimeter which makes a constant record of pressure, hence showing the course of the plane in altitude. Air-speed recorders also are used to make record of the speed of a plane on a test flight. Angle of attack indicators give warning of impending stalls.

Rigging and Testing. A pilot should know something of the proper method of assembling planes. When shipped from the factory they come knocked down, and it is necessary then to "rig," or assemble, them. This is a task requiring great care, for any undue stress or strain, due to an improperly rigged part of

the plane, may result in serious accident. The student is instructed in methods of rigging at the ground school. When a new plane is tried out, the pilot who takes it up tests carefully the response of the controls, and never attempts any difficult or complicated maneuvers until he is perfectly satisfied that the rigging is correct and the plane performing satisfactorily.

Preliminary Flights. A student is usually taken up in the air for an experience flight before he is allowed to operate the controls. This gives the instructor a chance to observe his reactions, and also gives the student an opportunity to become accustomed to the noise of the engine, the rush of the slipstream, and the sensation in level flight and gliding. The aim of the instructor is to develop the self-confidence of the student; hence from the beginning the student is drilled in essentials so that he will not make any bad mistake.

One purpose of these preliminary flights is to learn to handle the controls with a light and firm touch rather than a tense, nervous grip. This delicate handling of the controls is basic because in no other way can the pilot *feel* how the plane is acting. The first step in training is to develop the proper sensitiveness, and the instructor will make corrections of errors until this "feel" of the performance of the plane is satisfactorily acquired. Instructors teach the use of the various controls in different orders.

In order to acquire this "feel," students are usually allowed to handle one control at a time, until its use becomes instinctive. Perhaps the simplest control to learn is the elevator. The elevator is actually one control, both halves working as a single unit; but since it is divided in the center by the rudder, it is spoken of in the plural, as the "elevators." The elevators are operated by the forward and backward motion of the stick. The stick is situated between your knees. You now learn how to keep the nose of the plane level with the horizon. You are given some landmark upon which to sight the plane, and told to watch this as the elevator makes the nose rise or fall. You will find that pulling the stick back raises the nose, and that pushing forward lowers it. The instructor will warn you not to keep your eyes on the controls, but to have them fixed on the nose of the plane in reference to some distant landmark. You will then be told to raise the nose

slightly, and then bring it back on the horizon. You will perform this simple evolution until you accomplish it perfectly. The instructor will handle the other controls, but he will allow you complete control of the elevators, unless correction is necessary.

The lateral movement of the stick is usually the second thing to be learned. This affects the rolling motion of the ship. Pressure to the right lowers the right wing, and vice versa.

The use of the rudder is more difficult than that of the other controls, since it must be accurate. You are told to put your feet on the rudder-bar. A push to the left turns the plane left, and a push to the right accomplishes the opposite effect.

Gradually, you will be able to combine the uses of the several controls. The object of the preliminary flights is to become able to coördinate the action of the controls so that response to a change of course of the plane will be immediate and almost instinctive, rather than slow and studied.

Straight Flying. Training in straight flight, that is, with the plane's altitude constant, and with no deviation to right or left, is highly important in learning to fly. As soon as the plane has attained sufficient altitude, the engine is throttled down, and the student taught how to keep the plane on a level course, as illustrated in Figure 18. One of his first lessons is to move the nose of the plane frequently off its course for a moment so that he can look ahead. A second is that if the plane gives any sign of becoming unmanageable, he should push the stick forward, thus regaining flying speed and control.

In straight flight it is often necessary to correct for the propeller torque, which tends to swing the plane towards the left and also to make the left wing lower than the right. Some planes are designed to alleviate this inevitable effect on the wing, but normally the rudder must be employed to balance it. A student frequently overcorrects for this wing dip with the result that the plane skids, that is, slides outwardly when turning. After a while, maintenance of the requisite amount of "right rudder" becomes instinctive. Slow and careful correction of wing dip will avoid skidding.

Turns. When the plane changes its course of level flight, it turns. Ordinarily, pressure on one side or other of the rudder-

bar will cause the plane to turn. In making a turn it is necessary to "bank" the plane or tip it at an angle, as illustrated in Figure 19. The degree of bank required will vary with the speed of the plane at the moment and the tightness of the turn. At a slow speed, the angle of bank will be comparatively small. The ailerons must be used to make this bank.

Alexander Aircraft Corporation

FIG. 18. A PLANE IN STRAIGHT FLIGHT

It is possible to see from this picture how the plane is held parallel fore and aft with the horizon, in order that altitude will be neither lost nor gained. To prevent the turning of the plane to the left or right, the pilot must keep the wings level with the horizon and maintain a steady pressure on the rudder-bar.

The student must be taught to give the plane its proper angle of bank. If, as he sits in the cockpit, he feels the plane skidding as he turns, then he has not given the plane enough bank, and this is a common fault with beginners. Skidding is dangerous because it causes loss of speed, and may put the plane out of control. On the other hand, if the student banks the plane too

Armstrong Siddeley Motors, Ltd.

FIG. 19. A PLANE TURNING

This plane is making a gentle bank, *i.e.*, it is tipping a little to the right, in order to make a well-balanced right turn. The Tower Bridge of London may be seen in the foreground.

much (for a given angle of turn) then it slides inward, or slips: but this is not so serious a fault as too little bank. In judging the angle of bank the student looks at the changing position of the nose on the horizon, and this will also tell him the amount of turn.

Taxying. When a student has learned the use of the controls in the air, he is instructed how to roll the plane along the ground under its own power. This is called taxying. Before starting to taxy, the instructor will tell the student to check up on the action of his controls, and to do this each time before he starts. He will then be told to start off slowly, giving ample room to any other planes on the field, or any obstacle. Some instructors advise a zigzag course so that there will never be any danger of running into something because of the blind spot directly ahead of the nose of the plane.

The student will be told to note the position of the plane's nose relative to the horizon and the ground during the taxying stage. He will become accustomed to handling the plane under different wind directions. He will be cautioned particularly against the dreaded "ground-loop" or tendency of a plane to make too sharp a turn, with possible resultant damage. After the student learns to taxy in a straight line he is shown how to turn. Such turns require a coarse movement of the rudder and ailerons, while the elevators remain in neutral position. If the plane should ground loop, the student is instructed to throttle the motor and let the plane come to a stop as soon as it will.

Take-Offs. The term "take-offs" relates to maneuvering of the plane from the ground into the air. Taxying is normally applied only to moving the plane around the field in position for a take-off or bringing it back from a landing. Wind direction is particularly important in taking off, and you will be told to head into the wind, if possible, because this aids the take-off.

In taking off, you are told to open the throttle wide. The tail is lifted from the ground by means of the elevators. The ground speed is gradually increased until it is sufficient to lift the plane from the ground. When traveling at this velocity, the ship normally takes itself off the ground, although the pilot may help this by depressing the tail slightly, thus pointing the nose of the plane

upwards, ready to gain altitude. The essential point is to have flying speed from the moment the plane leaves the ground.

You should be sure to examine the surrounding terrain in advance so that, when the take-off is completed, you may have a good idea of what to do should difficulties arise due to engine failure or down currents of air.

Landings. In practice, landing includes everything from the moment the plane is put into a glide until it comes to rest on the ground. Four steps are normally distinguished:

1. The glide
2. Leveling off
3. Stalling
4. Rolling over ground to a stop.

The actual process of landing is not difficult, once the student has acquired the knack. Good landings call for close timing and careful judgment of distance. Any individual who is not able to make good landings can usually find his trouble there. With the average plane the landing speed is between 35 and 55 miles an hour, so it is easily seen how quickly the various steps in the maneuver must be carried out.

The ideal landing is known as a "three-point" landing, in which the two wheels and the tail skid touch the ground at the same time. To get this result flying speed must be lost just at the moment the plane is flying parallel to the ground. Instructors try to teach their students to land their planes so that after leveling off the plane will land on the ground within 50 to 100 yards. Figure 20 shows a ship leveling off.

Normal landings are made against the wind. The pilot picks out his runway on the ground and turns the ship downwards in its direction. You will be warned not to look down over the side to gauge the distance to the ground, but rather to keep your eyes well ahead of the plane. As the ground approaches, the glide is gradually flattened out. This is called leveling off. The student must learn by repeated practice how long the glide will take until leveling off should occur. After the plane levels off, it floats for a while and then begins to settle. The pilot sits in the middle of his seat and keeps the wings level, pulling back on the stick

very gradually to keep the nose from dropping, but without gaining altitude.

If a smooth landing is to be made the plane must be kept in the air as long as possible. Just before the instant when the nose can no longer be held level the elevators are raised to the limit. This "stalls" the plane and makes both the wheels and the tail skid touch simultaneously. When the plane finally touches the ground the pilot allows it to roll until it comes to a stop.

The Fairey Aviation Company, Ltd.

FIG. 20. A PLANE LEVELING OFF TO LAND

When leveling off, the ship gradually loses speed, until it reaches a point at which the lift of the air becomes less than the pull of gravity, and the ship "stalls," that is, drops on to the ground. This is the famous British "mystery ship."

Climbs and Glides. Early in your training, you must learn how to climb and glide. As soon as enough speed has been attained after the take-off, the pilot points the nose of the plane upwards, maintaining enough headway to avoid the danger of loss of control. If the engine heats, as it may do in warm weather, at low levels, the pilot may climb a little way, then level off for a time and fly at a low speed until the engine is cooled, and then repeat the process. Above 3,000 feet it is rare for the engine to overheat.

When a pilot desires to lose altitude he puts the plane into

a glide, as in Figure 21. When a plane glides, the motor is throttled down, so that about 1 foot vertically is lost for every 7 feet of horizontal flight. The speed of the glide is much less than that of normal flying speed, usually about 35 per cent less, and as much as 50 per cent less than maximum speed. On the other hand, care must be taken not to lose too much speed, because in

FIG. 21. A PLANE IN A GLIDE

This Moth light plane is in a glide, *i.e.*, its nose is pointed slightly downward in order to lose altitude. In this photograph the ship is gliding in to land in the flying field below.

that event there would be danger of loss of control. If controls feel "soft," that is, if the plane does not respond readily to movement of the controls, the nose of the plane may be pointed down at a steeper angle, and greater speed is attained.

A glide is the normal method of landing a plane, because if a dive were employed the plane would have too much speed for a safe landing. A glide is the slowest method of losing altitude.

While the speed of the plane is judged mainly by the feeling of the controls, there are certain indications of the rapidity of the plane's flight. The hum of the wires, for example, is pitched lower with decreases in speed, and the pilot learns to know the right pitch for gliding speed. The danger of loss of flying speed when gliding is serious, because if the plane is too near the ground there may not be time to regain control before the ship crashes.

Stalls. Of all the things there are to know about flying an airplane, the most important is the *stall*. The stall is the most dangerous condition in flying; yet it would be impossible to land without going into a stall. Any loss of flying speed, either in a climb or a glide, will result in a stall, and a drop of the plane nose downward. If the stall is slight, that is, if the speed is only a little under flying speed, this drop will begin gradually and gently; but if the stall is great the nose will drop sharply. In every case the remedy for a stall is to push the stick forward, thus diving the ship and regaining flying speed. Of all causes of flying accidents the stall is probably the most common. At a high altitude there is ample time for recovery, but at a low altitude, or in a landing glide, there is no time to regain flying speed before the plane crashes nose down.

The instructor may stall the plane intentionally and often does so for the student's benefit; but the dangerous stalls are those which occur unintentionally. A pilot who has his mind fixed on the point of landing may omit to watch the action of his plane for a few seconds, with a resulting stall. The pilot must always govern his landing by the action of his plane, rather than try to make the plane glide too far.

Spins. An uncorrected stall usually results in what is known as the spin, or tail spin. In fact, when in a spin, the ship is in a stalled condition. A spin is a sort of gyrating stall. In this, the plane falls nose first, while the tail spins around and outside the nose, like a corkscrew. A spin can be accomplished intentionally by pulling the stick way back and pushing the rudder bar forward in either direction. The remedy for a spin is to put the rudder in neutral, push the stick a little forward of neutral, and go into a nose dive, whereupon flying speed is restored and the

pilot may recover control easily. There are a number of conditions which may cause a spin, such as excessive skidding or sideslipping, stalling in too steep a climb, too gradual a glide, or in a climbing turn at the take-off.

Solo Flying. All the preliminary training in flying is done with an instructor. Finally, the student is allowed to take the plane up by himself, after he has mastered the simple maneuvers, and after he has demonstrated his ability to take care of himself in the air. Before he can take advanced instruction, he must have time by himself in the plane so that he can attain that skill which comes only from practice and the realization that the action of the plane depends on himself alone. The first solo flight consists of no more than a few turns and a landing, and occupies but a few minutes. Gradually the difficulty of the maneuvers is increased and the length of time in the air is extended.

Advanced Instruction. While a student may obtain his private pilot's license without performing the more complicated maneuvers, yet safety in the air may depend on his ability to handle a plane with more than elementary skill. Hence, advanced instruction is highly desirable.

For example, while the normal landing is made into the wind, under some conditions this is impossible. The runway may not be long enough to fly directly into the wind. The pilot here brings his plane down in a crab-like fashion. If the wind is east and the pilot wants to fly south, he travels southeasterly, the wind velocity keeping him on his course. He does not straighten out the plane for the landing until just before actual contact is made with the ground. After he touches the ground he must take great care not to ground loop, due to the cross wind on the tail of the plane, and on the windward wing.

Advanced instruction will normally include figure eights, which means that the plane must be flown level, and turned to the right and left over a specified course at a constant altitude. The student is given three landmarks, one at the center, and one at each extremity, and he is supposed to keep this course. This is not easy to do at first and beginners frequently skid badly on the turns. In the same class are other advanced maneuvers such as spiral and spot landings.

Stunting. The line between advanced maneuvers and stunting is extremely close. Stunting puts a great strain on the structure of the plane, and is highly dangerous when one is too near the ground. Performing stunts or acrobatics often involves a dive, and when the plane is brought out of a dive too sharply, the result sometimes is to have it "mush" flat to the ground.

Acrobatics are fairly well standardized, just as are the simple evolutions in flying. Looping the loop, for example, is regarded now as a fairly simple maneuver. Tail spins are recognized stunts which skilled pilots regard as perfectly safe. In the half-roll the plane turns on its back, goes into a dive, and comes out of it headed in a direction opposite to the original line of flight. In the complete or barrel roll, the plane turns entirely over and ends in level flight again, headed in the same direction. In addition, there are more complicated stunts, such as a half-roll off the top of the loop where the plane is made to roll when upside down in the loop and comes right side up without completing the loop. This is also known as the Immelmann turn.

In the falling leaf, the plane is made to lose altitude in a succession of sidewise swings, resembling in effect the falling of a leaf from a tree: it is a sort of combination spin and sideslip. Another spectacular stunt is to head the plane into a strong wind and make it turn first one way and then the other, which is known as skating. There are other stunts which are treated in greater detail in the chapter on that subject.

Cross-Country Flying. Before a student gets very far in flying he must take a cross-country flight. To do this requires plotting the course on a map, and planning out carefully how long the trip will take. He must keep watch of the country at all times to see what opportunities offer for forced landings in case of engine failure. For his first cross-country flights he should choose good weather, although later he may feel confident enough to fly when the weather is not so perfect.

Cross-country flying is now regarded as safe, because engines are reliable enough to make failure a remote possibility. Even when failure occurs, there is usually enough advance warning to allow the pilot to pick out a safe landing field. Pilots once regarded altitude as essential for safe cross-country flight, but at

present the tendency is to fly fairly low and put one's trust in the engine.

But, after all, the danger of the engine's cutting out is never completely eliminated. The practice of forced landings is, therefore, of extreme importance.

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This chapter has given the student an idea of what flying is, and how it is done. The question arises in his mind, "Am I qualified to become a pilot?" This question is now to be discussed.

SUGGESTIONS FOR READING ON THE PROCEDURE OF TRAINING

Swoffer, Frank A., *Learning to Fly,* chaps. I, II. Pitman.
Macmillan, Norman, *The Art of Flying,* chaps. I, IV. Mitchell.
Studley, Barrett, *How to Fly,* chap. VI. Macmillan.

Questions for Review

1. Make an outline, from memory, of the steps in flight training.
2. Compare the steps of flight training with those of driving a car. Sailing a boat. Riding a horse. With other things you have learned.
3. Examine the cockpits of three makes of plane. State the differences you observe and explain them.
4. Differentiate between the construction of these three planes.
5. Draw a diagram of the rudder bar and stick and the method whereby they are connected to the rudder, elevator, and ailerons.
6. What is your opinion of "Fly Fast" as a motto?
7. What are the principal subjects taught in the ground school? What is the chief value of each?
8. What do you expect to find the most difficult elementary maneuver to learn? Why?
9. To what use is the stall put in ordinary flying?
10. What have you learned about the steps in training which you did not know before?

CHAPTER III

THE QUALIFICATIONS OF A PILOT

No SET rule can be made as to who can learn to fly and who cannot. A certain degree of physical fitness and of mental alertness is necessary, to be sure, in order to comply with the government requirements for obtaining a license. These qualities are not, however, sufficient in themselves to allow a man to become a good pilot. Nor can the inherent quality which makes a pilot successful be defined. An instructor once summed up his experience in a proverbial remark: "After the first two hundred hours in the air, plain horse sense is all that counts."

Effect of Age. The minimum age at which a private license can be secured is sixteen. Generally, however, training for flight is not considered advisable under sixteen. Clarence Chamberlin, the transatlantic flyer, has done a good deal of experimenting with boys twelve and fourteen years of age. He found that they were able to learn to fly quickly. The "reaction time" at this age is considerably shorter than that of people in middle life.

People between twenty and thirty are perhaps the best subjects for training, as the mind is then more receptive and adaptable. On the other hand, no one who is physically sound and active, and in full possession of his mental abilities, is too old to learn to fly, though not adapted to the strain of professional flying. Age alone is not a determining factor, although it is noteworthy that the most famous pilots are usually young men.

Age as a restrictive factor will probably become less and less important as flying conditions become more safe, and planes become more "foolproof."

Women as Pilots. There is a real opportunity now for flight training for women, although women, with some notable exceptions, have not yet proved their prowess in the air. There is, however, no reason why women should not make excellent pilots.

Many women possess a coolness in emergencies which is superior to that of men.

The present ratio of men pilots to women pilots in the United States is 100 to 1. It is probable, however, that the proportion of licensed women fliers will increase at a rapid rate. Aviation is a field in which women have comparatively few handicaps.

Physical Qualifications. If any person desires to obtain a pilot's license he must take a physical examination to prove that he is free from any organic defect or disease which would interfere with his safe operation of the plane.

Physical health for an airplane pilot does not necessarily include great muscular development, although pilots as a class give the impression of strength and robustness. Physical health in airplane parlance is directed mainly towards clearness of vision, sense of equilibrium, and, of course, proper action of lungs, heart, muscles, and nervous reflexes. Soundness in these is required for the private license.

In the case of a transport pilot, the physical requirements are more rigid. One who qualifies for this service must have a good physical record; be sound in pulmonary, cardio-vascular, gastro-intestinal, central nervous, and genito-urinary systems; be free from diseases of the ductless glands; have no obstructive or diseased conditions of the ear, nose, and throat, and no difficulties with the maintenance of equilibrium, which might interfere with flying.

Vision. Good vision is highly essential. For a private pilot requirements for visual acuity are 20 50 in each eye, although if vision can be corrected to at least 20 30 by his goggles he may be accepted, provided he has good judgment of distance, no diplopia (double vision), no color blindness, and no disease of the eye. The importance of vision can be readily realized when it is considered that an average landing takes place at a speed of approximately 45 miles an hour, and judgment of speed and distance is essential if a safe landing is to be made. No students will be accepted with acuity less than 20 50, and in a private pilot only when the experience of the applicant is sufficient to warrant a waiver being granted.

Good vision is also highly important in flight because the

pilot of a plane, much like the pilot of a vessel, frequently steers his course by keeping the nose of the plane headed towards some distant object. He should be able to see a distant horizon to be sure that his plane is on an even keel. He should also be able to see other ships out of the tail of his eye.

Requirements for vision are much stricter in the case of industrial, commercial, and transport pilots where the visual acuity must be normal or 20/20 for the transport and limited commercial grades, and 20/30 for the industrial.

Hearing. Theoretically a deaf person might fly a plane with little difficulty, provided his internal ear were not involved, causing a disturbance of equilibrium. The noise of the motor, the rush of the air back from the propeller, the hum of the wires and struts, all combine to form a noise which precludes conversation without speaking tubes. A good sense of hearing, however, is highly important to the safety of the pilot. He must be able to distinguish sounds in the engine which indicate trouble. As long as the engine is functioning properly, the pilot has little to fear, but he should be able to pick out any unusual sound which would indicate that something is wrong with the engine.

The pilot will also become accustomed to the vibrations in the rigging wires, and any variations in pitch will indicate to him when trouble may be expected. A good sense of hearing for the pilot does not mean necessarily the ability to notice very faint sounds, but rather the ability to distinguish those sounds which denote trouble in the engine or plane. Of course, a pilot should be able to converse with his mechanic and passenger, and also hear radio signals.

This is interpreted, however, in a different manner for private pilots and for industrial, commercial, and transport pilots. The private pilot is not responsible as is the transport pilot for the lives of passengers, nor is he compelled to make flights on regular schedule.

If, however, a flyer has had a great deal of experience, the Secretary of Commerce may grant a waiver for physical defects, provided his experience is deemed to overbalance these defects, and this waiver will hold good until canceled. The physical re-

quirements, therefore, may be modified under conditions which warrant it.

It is difficult to foretell how great a handicap any physical defect will be to a pilot. There is an interesting example of this statement. An English airman of marked ability lost the use of one eye through some accident. The English government saw no sufficient reason for revoking his license; therefore he continues to fly. Nevertheless, he may sometime be put in a critical position, from which he will not be able to extricate himself. It takes both eyes to give a good measure of distance.

Mental and Temperamental Qualifications. A good pilot must be possessed of certain qualities besides those connected solely with physical fitness, but, in general, a physically fit person is likely to possess these other qualities. Many authorities think that mentality is more important in development of the air pilot than physique alone, and undoubtedly the best pilots are extremely alert mentally. No more than average intelligence, however, is required for learning to fly, but this should be coupled with natural aptitude, judgment and decision, the ability to concentrate, and courage and coolness in emergencies. Most pilots, of course, have duties to perform other than merely flying a ship. Sometimes these duties are highly specialized, and require unusual qualifications in themselves. (See Figures 22 and 23.)

Natural Aptitude. Natural aptitude is a difficult term to define, but, in reality, it amounts to no more than the ability of an individual to adapt himself to air conditions. Some persons are temperamentally unfitted for flying, but they are comparatively few. It was once thought that natural aptitude could be discovered at once by taking a prospective student for a test flight, but in many cases this is not true. Many individuals who later have become experienced and capable pilots feel a strangeness and a sense of novelty on their first venture in the air, and give no indication of the aptitude which they later display. It is the ability to control one's reactions which counts rather than the reaction itself. The comment has often been made that those who show the greatest courage under the fire of an enemy are often those who are really most afraid, but who are able to control their fear.

On the other hand, some individuals entirely lack this neces-

Fairchild Aviation Corporation

FIG. 22. SOME PILOTS MUST HAVE UNUSUAL QUALIFICATIONS

This pilot's job is to fight forest fires. The aerial fire warden must be something more than just a flyer. This picture was taken in the North Woods of Quebec.

Official Photograph, U. S. Navy

FIG. 23. MILITARY SERVICE IS THE SEVEREST TEST

There is perhaps no greater test of any man's physical and mental abilities than those of war—in the air. This illustrates a torpedo attack on a battleship.

sary aptitude. They are not able to coördinate brain and muscle quickly enough to make flying safe for them. It is not a simple matter, however, to determine this in advance, although attempts have been made to do so. (See Figure 24.) Even the most skilled

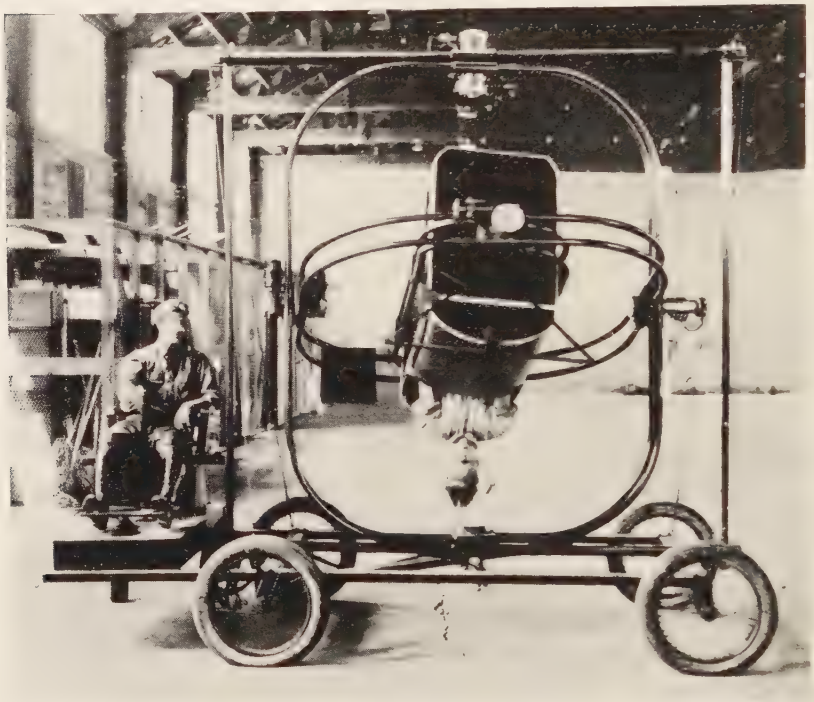


FIG. 24. CAN FLYING APTITUDE BE PREDETERMINED?

The purpose of this contrivance, the "Orientator," is to help determine the likelihood of a candidate's becoming a successful pilot. The cockpit is provided with a stick and rudder-bar which put the student in the same position that he would find himself in if he operated the controls the same way in a plane. The instructor has a duplicate set of controls, which can, if he desires, be used to interfere with the student's maneuvers. In the hands of a trained observer, this device proves useful.

pilots have developed this coördination only after long experience. The student is constantly meeting new situations. Only careful instruction and continuous experience can develop the ability to meet them instinctively and well.

Judgment. Judgment is, perhaps, the most important quality in flying. It cannot be acquired, however, without experience, and is developed over a long period. The majority of accidents in the air are probably caused by errors in judgment, sometimes through ignorance, sometimes through overconfidence, and sometimes through inability to form any judgment. It is the purpose of flight training to develop the student's sense of judgment so that under normal flying conditions he can be trusted to do the right thing. When an emergency occurs, he will have a background to enable him to do the right thing instinctively.

Decisiveness. Situations are constantly occurring in flying where a decision must be made immediately as to the proper course of procedure. This ability to make an instantaneous decision is highly important for the pilot's safety. If, for example, he goes into a tail spin, his judgment must correctly tell him how to get out of it, and his decision to act be carried instantly into effect.

Concentration. Even an experienced pilot cannot allow his attention to wander from the guidance of the plane. The student, of course, must develop an even higher degree of attention, and this at first will probably be difficult. The novelty of the sensation of being in the air, the noise of the motor and propeller, the difference in the "feel" of the controls from, for example, the wheel of an automobile, will all tend to distract him from the one essential task—that of guiding the plane.

There is a great difference between concentration, which is mental alertness, and nervous tension, which is overdeveloped concentration. The student should never allow his imagination to run riot, and conjure up problems and situations which do not exist. He should think of what is happening and not of what might happen. The mere fact that the student is mentally alert to what is occurring in the plane will make him aware of trouble the moment it appears.

Courage and Coolness. A person may be nervously high strung, yet be able to keep his head when emergencies arise. In many cases pilots of nervous temperament become extremely adept in flying, because of the high degrees of mental alertness and concentration which this implies. The preliminary physical

examination determines to some extent a student's nervous make-up. The instructor can usually tell whether the student's nervous condition is a bar to flight instruction after 5 or 6 hours in the air with him, although even this would not be proof positive of inability to fly. The time required to overcome natural nervousness will vary widely with the individual.

Courage does not imply a blind disregard of personal consequences. It is far more the ability to keep imagination and fear under control; it includes a coolness in emergencies which allows the individual's judgment to select the best possible course of action under the circumstances. "Safety first" is an excellent rule for any student to follow; that is, choose the method which is certain to result safely, even though it is not spectacular. The spectacular should never be necessary unless it happens to be also the safest procedure. Too many students have been killed "showing off."

Confidence. The student should have confidence both in the plane and in the instructor, at the outset. Both the planes and the pilots in the majority of instruction schools are selected with the question of the student's safety in mind. On the other hand, the student should not have too much confidence in himself. This should be acquired gradually, and only in measure as experience brings good judgment. A student should be able to tell when he is capable of conducting a plane safely under normal flying conditions, but many are not, and the instructor's judgment must prevail. Overconfidence in ability to make turns, difficult landings, and other maneuvers has caused innumerable mishaps.

Classes of Pilots. All pilots must secure an operator's license, for interstate flying; intrastate flying may still be done by unlicensed pilots and planes. The license differs according to the type of flying. There are four classes of pilots:

1. Private, including student pilots
2. Industrial
3. Limited commercial
4. Transport.

Private pilots (not designated as students) may pilot licensed

aircraft but may not carry persons or property for hire. Nor may private pilots give instruction to students, for hire. Figure 25 shows a private pilot's license.

Special licenses are issued to students during the time they are receiving flight instruction, which specify the area within which the student may fly. Student pilots are supposed to fly only for the purpose of receiving instructions. Private pilots are entitled to fly licensed aircraft, but are forbidden to carry passengers or cargo for hire. They are not allowed, furthermore, to give flying instruction to students. A private pilot may carry passengers, but not for hire.

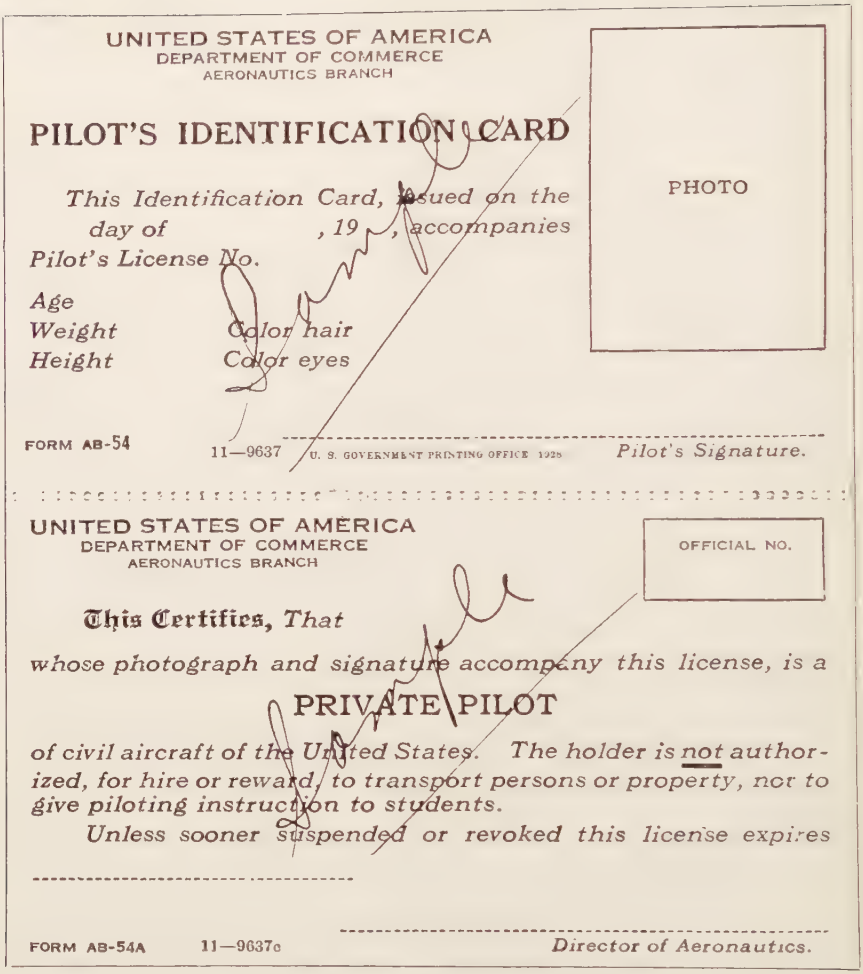
Industrial pilots are licensed to fly planes carrying property for hire. They are not allowed to carry passengers for hire, or give instructions to students for hire.

Limited commercial pilots may carry persons and property for hire within certain geographical limits. They are not, however, licensed to give flight instruction for hire.

Transport pilots may carry persons and property for hire without restriction as to locality. They may also instruct students for hire.

Examinations for License. Application for pilot's license of any kind must be made under oath and filed with the Secretary of Commerce. All applicants, including students, must take a physical examination. A certain number of solo flying hours is required for each type of pilot. A private pilot must have had 10 hours of solo flight, industrial and limited commercial classes must have had 50 hours, while transport pilots are required to have had 200 hours of solo flying.

1. Examinations for transport pilots. These are naturally more rigid than those for limited commercial, industrial, and private pilots. There are three parts to them: first, an examination on the air traffic rules and the sections of the Air Commerce Regulations dealing with the privileges and limitations of pilots and the inspection and operation of aircraft. Second, there is a technical examination on engine and plane mechanics and rigging, plus an elementary examination in meteorology and navigation. Third, there is a practical flight test, which includes not



UNITED STATES OF AMERICA
DEPARTMENT OF COMMERCE
AERONAUTICS BRANCH

PILOT'S IDENTIFICATION CARD

PHOTO

This Identification Card, issued on the day of , 19 , accompanies Pilot's License No.

Age
Weight *Color hair*
Height *Color eyes*

FORM AB-54 11—9637 U. S. GOVERNMENT PRINTING OFFICE 1928 *Pilot's Signature.*

UNITED STATES OF AMERICA
DEPARTMENT OF COMMERCE
AERONAUTICS BRANCH

OFFICIAL NO.

This Certifies, *That*

whose photograph and signature accompany this license, is a

PRIVATE PILOT

of civil aircraft of the United States. The holder is not authorized, for hire or reward, to transport persons or property, nor to give piloting instruction to students.

Unless sooner suspended or revoked this license expires

FORM AB-54A 11—9637c *Director of Aeronautics.*

FIG. 25. PRIVATE PILOT'S LICENSE

This license is the least advanced of any, except the student's license. It permits the operation of an airplane, but not the carrying of passengers or goods for hire.

only normal take-offs and landings, but certain specified maneuvers.

a. From a height of 1,500 feet, with engine throttled, the applicant must make a 360 degree turn and land in normal landing attitude, with wheels touching the ground within 200 feet of a line designated by the Department of Commerce examiner.

b. From 1,000 feet, also with engine throttled, the applicant must make a 180 degree turn and land normally with wheels touching ground within 200 feet of the line.

c. The applicant must then do a series of five gentle figure-eight turns 800 feet altitude, and three steep figure-eights at 1,000 feet, both around pylons 1,200 feet apart. Then he must spiral from 2,000 feet in one direction with engine throttled, and land within 200 feet of the line.

d. Having demonstrated his ability to perform these simple maneuvers, the applicant must undertake a more complicated series of maneuvers, such as spirals, sideslips, climbing turns, and recovery from stalls and spins.

e. A triangular or rectangular course, at least 100 miles long, is laid out over which the applicant must fly, returning to place of take-off within five hours. Two obligatory landings must be made during this time, neither of them at the point of departure, and during each landing the plane must come to a complete rest. This test is not required if the applicant has had 100 miles of cross-country flying within a year previous to the test.

f. The pilot must also demonstrate his ability to land and take off in a cross-wind if the inspector requires it.

2. An industrial pilot is examined on rules and regulations, and must take all the practical flying tests required of transport pilots except that the cross-country flight is limited to 60 miles.

3. A limited commercial pilot is not required to take the cross-country flight, nor is he examined on meteorology or navigation.

4. A private pilot is required to know the rules and regulations of the Department of Commerce and, in addition, pass

certain simple flight tests. He must make three satisfactory landings to a full stop. He must also perform five gentle and three steep figure-eight turns from 800 to 1,000 feet, respectively. He must also spiral in one direction from an altitude of 2,000 feet, with engine throttled, and land within 500 feet of the line designated by the examiner.

Applicants for students' licenses are not required to take these tests or examinations, except physical examinations.

FIG. 26. LEARN THE RULES OF AIR TRAFFIC

More and more, accidents in aviation are due to traffic jams. Many of these are the result of not knowing the rules of the road. It is the automobile story all over again.

Air Traffic Rules. Every pilot must know the rules of air traffic as established by the Department of Commerce. The importance of traffic regulation becomes more important every year, and bids fair to affect greatly the flying of the future. Failure to understand the rules of the air is fraught with the most serious consequences. (See Figure 26.) These rules are, after all, easy to learn. They are given below:

Right-Side Traffic. Aircraft flying in established civil airways, when it is safe and practicable, shall keep to the right side of such airways.

Giving-Way Order. Craft shall give way to each other in the following order:

1. Airplanes.
2. Airships.
3. Balloons, fixed or free.

An airship not under control is classed as a free balloon. Aircraft required to give way shall keep a safe distance, having regard to the circumstances of the case. Three hundred feet will be considered a minimum safe distance.

Giving-Way Duties. If the circumstances permit, the craft which is required to give way shall avoid crossing ahead of the other. The other craft may maintain its course and speed, but no engine-driven craft may pursue its course if it would come within 300 feet of another craft, 300 feet being the minimum distance within which aircraft, other than military aircraft of the United States engaged in military maneuvers and commercial aircraft engaged in local industrial operations, may come within proximity of each other in flight.

Crossing. When two engine-driven aircraft are on crossing courses the aircraft which has the other on its right side shall keep out of the way.

Approaching. When two engine-driven aircraft are approaching head-on, or approximately so, and there is risk of collision, each shall alter its course to the right, so that each may pass on the left side of the other. This rule does not apply to cases where aircraft will, if each keeps on its respective course, pass more than 300 feet from each other.

Overtaking. 1. *Definition.* An overtaking aircraft is one approaching another directly from behind or within 70° of that position, and no subsequent alteration of the bearing between the two shall make the overtaking aircraft a crossing aircraft within the meaning of these rules or relieve it of the duty of keeping clear of the overtaken craft until it is finally past and clear.

2. *Presumption.* In case of doubt as to whether it is forward or abaft such position it should assume that it is an overtaking aircraft and keep out of the way.

3. *Altering course.* The overtaking aircraft shall keep out of the way of the overtaken aircraft by altering its own course to the right, and not in the vertical plane.

Height over Congested and other Areas. Exclusive of taking off from or landing on an established landing field, airport, or on

property designated for that purpose by the owner, and except as otherwise permitted, aircraft shall not be flown—

1. Over the congested parts of cities, towns, or settlements, except at a height sufficient to permit of a reasonably safe emergency landing, which in no case shall be less than 1,000 feet.

2. Elsewhere at height less than 500 feet, except where indispensable to an industrial flying operation.

Height over Assembly of Persons. No flight under 1,000 feet in height shall be made over any open-air assembly of persons except with the consent of the Secretary of Commerce. Such consent will be granted only for limited operations.

Acrobatic Flying. 1. Acrobatic flying means intentional maneuvers not necessary to air navigation.

2. No person shall acrobatically fly an aircraft—

a. Over a congested area of any city, town, or settlement.

b. Over any open-air assembly of persons or below 2,000 feet in height over any established civil airway, or at any height over any established airport or landing field, or within 1,000 feet horizontally thereof.

c. Any acrobatic maneuvers performed over any other place shall be concluded at a height greater than 1,500 feet.

d. No person shall acrobatically fly any airplane carrying passengers for hire.

e. Dropping objects or things. When an aircraft is in flight the pilot shall not drop or release, or permit any person to drop or release, any object or thing which may endanger life or injure property, except when necessary to the personal safety of the pilot, passengers, or crew.

Seaplanes on Water. Seaplanes on the water shall maneuver according to the laws and regulations of the United States governing the navigation of water craft, except as otherwise provided.

Transporting Explosives. The transporting of any explosives other than that necessary for signaling or fuel for such aircraft while in flight or materials for industrial and agricultural spraying (dusting) is prohibited, except upon special authority obtained from the Secretary of Commerce.

Foreign Air Commerce. Until otherwise provided, the laws of the United States and regulations made thereunder with respect to the entry and clearance of vessels engaged in foreign commerce are hereby made applicable to aircraft engaged in foreign air commerce.

Aircraft Lights

Airplane Lights. Between one-half hour after sunset and one-half hour before sunrise airplanes in flight must show the following lights:

1. On the right side a green light and on the left side a red light, each showing unbroken light between two vertical planes whose dihedral angle is 110° when measured to the left and right, respectively, from dead ahead. These lights shall be visible at least 2 miles.

2. At the rear and as far aft as possible a white light shining rearward, visible in a dihedral angle of 140° bisected by a vertical plane through the line of flight and visible at least 3 miles.

Airship Lights. Between one-half hour after sunset and one-half hour before sunrise airships shall carry and display the same lights that are prescribed for airplanes, excepting the side lights shall be doubled horizontally in a fore-and-aft position, and the rear light shall be doubled vertically. Lights in a pair shall be at least 7 feet apart.

Balloon Lights. A free balloon, between one-half hour after sunset and one-half hour before sunrise, shall display one white light not less than 20 feet below the car, visible for at least 2 miles. A fixed balloon, or airship, shall carry three lights—red, white, and red—in a vertical line, one over the other, visible at least 2 miles. The top red light shall be not less than 20 feet below the car, and the lights shall be not less than 7 nor more than 10 feet apart.

Lights When Stationary. 1. Between one-half hour after sunset and one-half hour before sunrise all aircraft which are on the surface of water and not under control, or which are moored or anchored in navigation lanes, shall show a white light visible for at least 2 miles in all directions.

2. Balloon and airship mooring cables between one-half hour after sunset and one-half hour before sunrise shall show groups of 3 red lights at intervals of at least every 100 feet, measured from the basket, the first light in the first group to be approximately 20 feet from the lower red balloon light. The object to which the balloon is moored on the ground shall have a similar group of lights to mark its position.

By day, balloon and airship mooring cables shall be marked with tubular streamers not less than 8 inches in diameter and 7 feet long and marked with alternate bands of white and red, 20 inches in width. The object to which the balloon or airship is moored on

the ground shall have the same kind of streamers, which must be in the same position as the lights specified herein.

Signals

Distress. The following signals, separately or together, shall, where practicable, be used in case of distress:

1. The international signal, S O S, by radio.
2. The international-code flag signal of distress, NC.
3. A square flag having either above or below it a ball, or anything resembling a ball.

Signal When Compelled to Land. When an aircraft is forced to land at night at a lighted airport it shall signal its forced landing by making a series of short flashes with its navigation lights if practicable to do so.

Fog Signals. In fog, mist, or heavy weather an aircraft on the water in navigation lanes, when its engines are not running, shall signal its presence by a sound device emitting a signal for about five seconds in two-minute intervals.

Take-Off and Landing Rules

Method. Take-offs and landings shall be made upwind when practicable. The take-off shall not be commenced until there is no risk of collision with landing aircraft and until preceding aircraft are clear of the field. Aircraft when taking off or landing shall observe the traffic lanes indicated by the field rules or signals. No take-off or landing shall be made from or on a public street or highway without the consent of the local governing authority and the approval of the Secretary of Commerce.

Course. If practicable, when within 1,000 feet horizontally of the leeward side of the landing field the airplane shall maintain a direct course toward the landing zone.

Right over Ground Planes. A landing plane has the right of way over planes moving on the ground or taking off.

Giving Way. When landing and maneuvering in preparation to land, the airplane at the greater height shall be responsible for avoiding the airplane at the lower height and shall, as regards landing, observe the rules governing overtaking aircraft.

Distress Landings. An aircraft in distress shall be given free way in attempting to land.

Angular Limits. The angular limits laid down in these rules will be determined as when the aircraft is in normal flying position.

Reports

Logs and Navigation Reports. The owner or operator of every licensed aircraft shall keep a navigation and engine log book and shall quarterly transmit to the Secretary of Commerce a navigation summary report, in duplicate, showing the number of hours and the approximate number of miles the aircraft has been flown during the quarter, the duration of the use of each engine, the engine installation and repairs, and the plane structure and rigging changes and repairs.

The log books shall be carried in the aircraft at all times when such aircraft is away from its home airport.

Accident Reports. Where serious injury to persons or property is suffered or death results in operating licensed aircraft, the owner of such aircraft shall immediately report, by telegraph or telephone, to the Secretary of Commerce, the license number or identification number of the aircraft and the time and place of the accident. All accidents in the operation of licensed aircraft which result in injury to the aircraft shall be reported without delay on the form provided for that purpose.

Repairs after Accident Reports. After repairs have been made on a licensed aircraft which has been seriously damaged, the licensed owner shall make full report to the Secretary of Commerce of the kind and extent of repairs made to the craft.

Flying Seriously Damaged Airplanes. A licensed airplane which is seriously damaged must not be flown with passengers for hire until it has been fully repaired and its flying condition approved by an inspector.

Deviation from Air Traffic Rules

The air traffic rules may be deviated from when special circumstances render a departure necessary to avoid immediate danger or when such departure is required because of stress of weather conditions or other unavoidable cause.

* * * * * * * *

The qualities of a good pilot are difficult to define; merely by reading a long exposition of the subject, you will not be able to decide whether or not you are qualified to be a successful pilot. The only means by which you will be able to judge at all whether you have either taste or aptitude is by actual flying. The subject of preliminary flights is treated in the next chapter.

SUGGESTIONS FOR READING ON QUALIFICATIONS OF A PILOT

MACMILLAN, NORMAN, *The Art of Flying,* chap. II. Mitchell.
JONES, BYRON Q., *Practical Flying,* chaps. III to VII. Ronald.
UNITED STATES DEPARTMENT OF COMMERCE, *Physical Standards for Airplane Pilots.* Government Printing Office.
HODGINS AND MAGOUN, *Sky High,* chap. I. Little, Brown.

QUESTIONS FOR REVIEW

1. Of the famous flyers you have read about, what would you say of their mental and moral qualities?
2. Interview some pilot of your acquaintance as to the qualifications for flying. To what extent do they agree with the ones described in this chapter?
3. State your own qualifications for becoming a pilot. Ask a friend to rate you. Compare the results.
4. Name the classes of pilots, their privileges and restrictions.
5. What are the requirements for the examination of a transport pilot?
6. What differences do you observe between the Air Traffic rules and rules governing automobile traffic? How do you account for these differences?
7. Enumerate the provisions relating to acrobatics.
8. What are the distress signals?
9. Enumerate the rules for taking off and landing.
10. Prepare in condensed form, for your own note book, a very brief summary of the Air Traffic rules.

PART TWO

PREPARATORY INSTRUCTION

CHAPTER IV. PRELIMINARY FLIGHTS

CHAPTER V. ELEMENTS OF AERODYNAMIC THEORY

CHAPTER VI. METEOROLOGY

CHAPTER VII. HOW THE CONTROLS ARE OPERATED

CHAPTER VIII. AIRPLANE INSTRUMENTS

CHAPTER IX. ENGINES AND PROPELLERS

Part Two explains the work preparatory to actual drilling in the air. No one is qualified to take flight instruction until he has gone through this preparatory work. Although to a considerable extent theoretical, a knowledge of this theory is essential to the rapid and certain mastery of this subject.

The first chapter in this section describes the preliminary flights which he is to be given in order to familiarize him with the new medium in which he is to travel. Next follows an exposition of aerodynamics—those physical laws which make possible the sustention of heavier-than-air machines. Meteorology follows next, a continuation of the same subject, especially in its application to the weather. In Chapter VII, the controls of the airplane are explained, this being highly important, since all progress through the air depends on the way they are handled. Chapter VIII discusses airplane instruments, their construction, operation, and use. The last chapter in Part Two treats of the power plant, that is, of engines and propellers.

CHAPTER IV

PRELIMINARY FLIGHTS

The object of the first few hours of instruction is to give the student a general idea of aviation. It resembles the orientation courses which some colleges give to their entering classes to familiarize them with the aims, objects, methods, and procedure which will affect them in their new environment. The average person who learns to fly has had little actual experience with planes or flying. He may have read a great deal about it, but, however wide his reading has been, the actuality is quite novel and strange.

The first endeavor of the pilot-instructor is to familiarize the beginner with the mechanism which operates the plane upon the ground and through the air, with the functions of the various controls, and with the instrument board. He is given a bare outline of the main principles which future lessons will take up in detail. If the student has done some reading on the subject of airplane construction and operation it will be much easier for him to assimilate the information given by the pilot. The purpose of a book on how to fly is to prepare for and supplement the practical demonstrations given by the instructor. Expert pilots themselves are occasionally somewhat hazy as to why a plane acts in a certain manner, even though they are absolutely certain from their own experience that the action is thus and so. Nor is it possible for them to explain operations at great length during the flight because of the difficulty of communicating in the plane. The student must be prepared to use some textbook in addition to the actual flight instruction.

Clothing. It is well, before making flights of any length, to give some thought to suitable costumes. (See Figure 27.) Various types of costumes are worn, in accordance with the frequency of their use, with climatic and weather conditions, and with one's

personal ideas of comfort. Flying suits have a price range of from $10 to $300. The clothing of the student is governed by few requirements, since it has merely the purpose of protecting his person and clothes. These requirements are chiefly that the clothing should be suitable to heat conditions, that it should shield him from the wind and dampness, and that it should be sufficiently ventilated.

The helmet and goggles are, perhaps, the most essential part of his attire, since the head of the pilot of an open plane is much exposed. This helmet is made of leather or cloth, lined in winter with fur and in summer with silk or chamois. Black leather helmets have been found unsatisfactory because the color tends to "run." The helmet is fastened by a chin-strap, and often in cold weather is supplemented by a leather hood and face-mask. The goggles are held in position by an elastic strap which goes around the head outside of the helmet. Goggles should be made of non-shatterable glass; the best type has cup-shaped glasses to give wide vision. If the pilot's vision is defective he may obtain special lenses ground according to the prescription for his eye-glasses. Sponge rubber binding of the goggles is more comfortable than leather, but requires sufficient ventilation.

The suits themselves are either "shells," covering the whole body, or three-quarter-length jackets. Winter suits are often of leather or duck, lined with fur or fleece. Summer suits are made of khaki or twill, gauntlets are made of leather and may be either gloves or mittens, the latter being considerably warmer. The legs and feet of the pilot need no extra covering in summer, but should be protected in the winter by fleece-lined boots or puttees. Overshoes are often worn.

Introductory Instruction. In order to reduce to a minimum the explanations required while actually in the air, the instructor gives some preliminary instruction just before taking off. He demonstrates the way in which the movements of the stick raise or depress the ailerons and the elevators, and in which the rudder-bar actuates the rudder. In many cases, he puts wooden blocks under the wheels to prevent the plane from moving ahead, or in planes equipped with brakes these are set and, while the engine is running, he allows you to see the tail lifted and lowered by the

A. G. Spalding & Bros.

FIG. 27. THE COMMUNICATING, OR GOSPORT TYPE, HELMET

The Gosport helmet is equipped with a speaking tube, of which one extremity is connected with the ears of one pilot, and the other end terminates in a mouth-piece into which the other pilot speaks. The figure shows one pilot speaking to another by this means. Sometimes, during dual instruction, both pilot and student wear Gosport helmets. This illustration also shows examples of winter flying suits, and of the kind of boots, gloves, and goggles to wear.

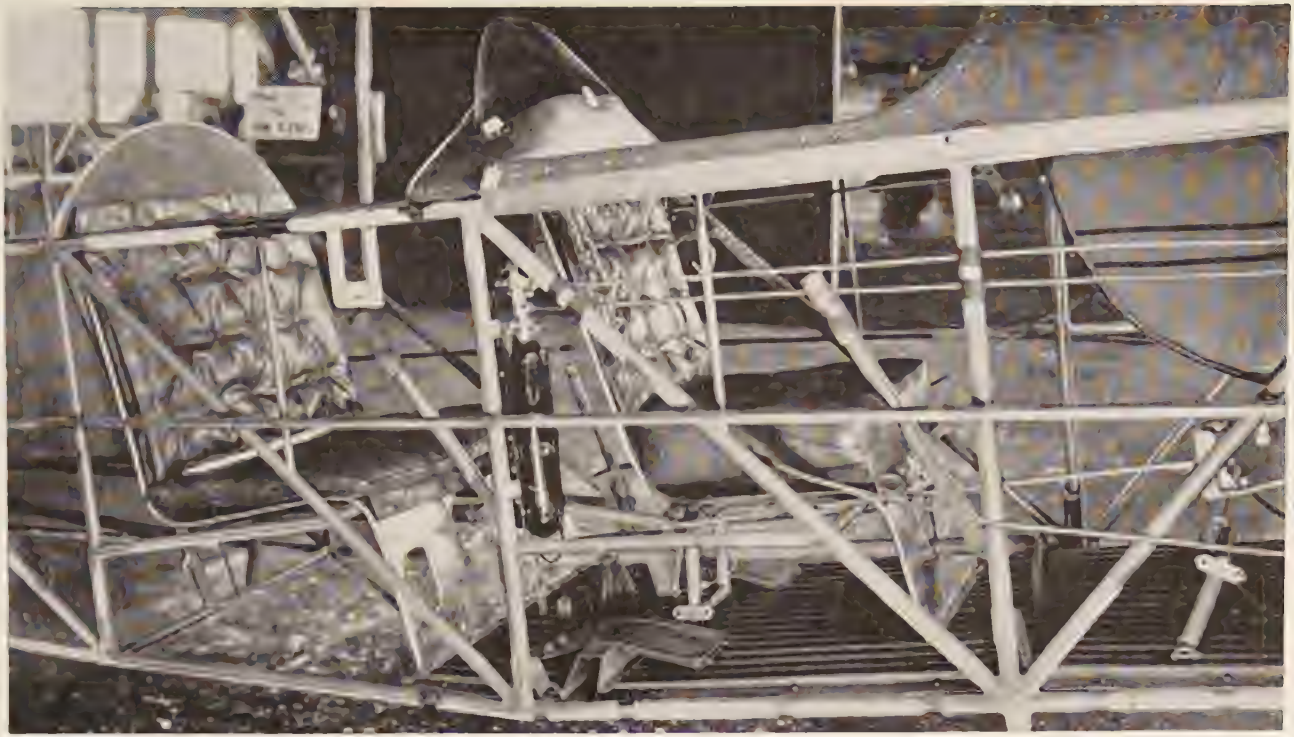
movements of the stick. He explains the purpose of the instruments on the instrument board. He indicates the opening of the throttle and the final pulling back of the stick requisite for the take-off. He describes the method of keeping the ship's nose on the horizon in flight, and the movements of the rudder and the stick to effect a turn. This introductory information is so brief and in such simplified form, that one can readily assimilate it.

The Dual System of Controls. After this explanation, the instructor-pilot himself controlling the plane, he allows you a few minutes' use of the rudder and of the stick. In order that such an experiment may readily be carried out, a system of dual controls is provided. This, briefly, means that there are two identical and entirely separate sticks, two rudder bars, and two throttles. One of these sets of duplicate controls is employed by the instructor, the other by the pupil. Both sets operate the plane simultaneously, so that control may at any moment be taken over from the student by the pilot, and vice versa.

Usually, there are two cockpits, one in the front of the plane for the instructor, and the other directly behind it for the student. Each cockpit contains one set of controls. Since the noise of the engine and the rush of the air would prevent the instructor from making his directions audible, the pupil frequently wears a communicating, or Gosport, helmet. (See Figure 27.)

This device consists of an ordinary aviation helmet equipped with a speaking tube which is attached like a head-phone to the ears of the helmet, and which passes into the instructor's cockpit. Frequently, a similar headgear is worn by the instructor so that he may hear the questions of the student. Occasionally both sets of controls are located in the same cockpit so that instructor and pupil may sit side by side; in this case, the proximity makes conversation less difficult.

The Cockpit. When you are in readiness for the preliminary flight, the instructor familiarizes you with the cockpit. (See Figure 28.) In large planes the cockpit is reached by steps; but in a small training plane you get aboard by climbing from the ground to the inner end of the wing, or onto a step on the fuselage, and from there over the edge of the cockpit into the seat. The seat is low-hung; but its height may be changed by the addition



Command-aire, Inc.

FIG. 28. HOW DUAL CONTROLS ARE OPERATED

This shows how both the primary and secondary controls are operated. Observe the stick and the rudder pedals. The throttle is designed so that it may be shifted to the right side, for left-handed pilots. The stabilizer control, with its notched quadrant, is at the student's left. Notice how the two sets of controls are interconnected.

of cushions, and it is imperative that you sit sufficiently high to be able to see the horizon plainly. Since you soon become accustomed to sighting directions in line with some part of the plane, you should always use the same number of cushions, so that the eye will always be at the same height. The instruments which indicate the altitude of the plane above the ground, the pressure of the oil, the amount of gasoline, etc., are arranged on a sort of dashboard directly before you (see first figure in Chapter VIII), the throttle is at the left side.

The instructor now acquaints you in some detail with the uses of the two main controls: the stick and the rudder-bar, sometimes by means of such a device as illustrated in Figure 29. The stick comes up from the floor of the cockpit between your legs just back of your knees; and it is mounted universally, so that you can move it forward, backward, or to either side. A forward movement effects a downward, and a backward movement an upward, course of travel. A movement to the left or to the right lowers the left or the right wing, as the case may be, allowing the wings to be held level, or to be slanted in order to make a turn.

The rudder-bar is attached to the floor beyond the base of the stick; it is in a horizontal position and crosswise of the plane. It is pivoted at the center, so that either end can be pushed forward or back by the feet. When you push the bar forward with your right foot, the plane makes a turn to the right; when the left, the plane turns to the left.

The Take-Off. When you have become accustomed to the appearance and functions of the mechanisms in the cockpit, the flight begins. The engine will be allowed to run for several minutes before you start, in order to warm up. You are fastened into the seat by a safety strap which buckles over your lap. The strap is always necessary, since ordinary occurrences, such as hard landing, are likely to throw you forward in your seat. The pilot clambers into his cockpit, speaks into the mouthpiece of your communicating tube to ask if you can hear him, and then taxies into that part of the field where he takes off.

Objectives of the First Flight. The initial flight is not so much for the purpose of instructing you in any particular phase

FIG. 29. USE OF STICK AND RUDDER-BAR

This is a device often used in ground schools for practicing the use of the rudder-bar and stick before actual control of the plane in the air is given the student. It consists of two cross pieces of wood, and a universally mounted "stick." This figure shows the control movements for a left turn.

of the handling of a plane as it is to give you a general and basic knowledge with which you will later be able to link the details of each phase as it is taught you. The objectives of this first flight are primarily two; in the first place, familiarization with the peculiarities of air travel and of the plane itself; and, secondly, observation of the means and methods of control.

Familiarization. The sensation of the first flight, since it is an unprecedented one, is in every instance strange and novel; and, before you control the plane yourself, you must become habituated to this new mode of locomotion so that it may not disconcert you. You realize that the roar of the motor, were it not for your Gosport helmet, would make communication impossible, and you experience a feeling of loneliness at being unable to converse. The strength of the air blast makes you appreciate your well-fitting goggles and warm clothes. There is nothing startling in the view seen over the edge of the cockpit, although it is an extraordinary one; newspapers have taught you to see the terrain in the terms of a checkerboard (see Figure 30), but the remoteness of the plane from the earth and your inability to recognize the taking-off place both tend to make you feel lost. You also notice how smoothly the plane flies, the lack of any sensation of speed, and your sinking feeling when the ship goes up or down over the air disturbances which are called "bumps."

The plane itself has some uncomfortable features, such as the draftiness of the cockpit, the odor of the exhaust, the presence of dirt and grease, and the obstruction of part of your view by the wings and the fuselage. But your interest is too much engrossed in other things to notice these discomforts, and the adjustment which you make to them is prompt and unconscious. Some people take their first flights in large transport planes. The sensations of these people are of a somewhat different nature from those experienced in a training plane. Some modern passenger planes are almost as spacious and quite as luxuriously equipped as a Pullman car. Although airplane motors are, in most cases, louder than the noise which a railroad passenger hears, the airplane, except in very rough weather, moves more smoothly than the train. Since airplanes bank on the turns, to allow for centrifugal force, passengers are not jerked from one side of their seats to

Boeing Air Transport System

FIG. 30. A CHECKERBOARD VIEW

This illustration shows the miniature pattern into which a city resolves itself when seen by the soaring pilot.

the other when the ship turns. Moreover, in cabin planes, the rush of air over the plane's surface is not noticeable, so that conversation is easily possible. Little advantage to the student can be derived (see Figure 31) from flights in such planes, except at the very beginning.

A few hours of flight will serve to dispel any feeling of nervousness which you may at first experience. The following excerpt is taken from the diary of a layman and is written concerning his first flight:

". . . The machine soon stopped climbing, and the instant she went level I noticed a quickening of my pulse. . . .

"In a few minutes I experienced a feeling with which I was thoroughly familiar. It was one that one has in dreams, of floating about, unsupported. I felt as though I had been drinking very heavily. . . .

"In two minutes this sensation passed away, and I found myself noticing a motion of our machine which might have been the result of running over railroad tracks. This was not of itself unpleasant, but it was discomforting because I did not understand what caused it. . . .

"We began at once to make a turn. The feeling of banking was unpleasant, and I accompanied it by a movement calculated to counteract this tipping. . . .

"I decided that by concentrating my mind upon an analysis of my feelings, I should of necessity become accustomed to my new instrument of locomotion. I knew I should be afraid if I allowed myself to become so. I *willed* that my muscles should relax. . . ."

It is important to acquaint yourself with the instruments. The majority of planes are provided with instruments for the pupil's cockpit only. In rare instances, some trouble of which the pilot is unaware might occur in the engine. In such a case, you should be able to recognize any warning registered by the instrument and communicate with him.

In the first hour or so of flight, you become somewhat acquainted with the action of the stick and the rudder. Your controls move simultaneously with those manipulated by the pilot who is flying the plane. By resting your hands and feet very

Cliché Michaud

FIG. 31. THE INTERIOR OF A LARGE PASSENGER PLANE

Some people's familiarization flights are made in a plane like this. The ship is used by a French air line.

lightly on the stick and the rudder you may learn how he uses them. When the plane has climbed to a suitable height, the pilot allows you to handle these controls, first one, then the other, then both of them together.

Alexander Aircraft Company

FIG. 32. BANKING

The pilot achieved this tilt of the ship and the corresponding curve to the left which the plane is in process of making, by moving the stick sideways to the left and by pushing his left foot forward on the rudder-bar.

These controls are both sensitive and precise in their response to your touch. You should learn to handle them lightly but firmly.

By such experimenting and by the instructor's corrections of your maneuvering, you are soon able to fly straight ahead and to make gentle turns with comparative smoothness.

Observation. Throughout this familiarization process, you learn a good deal from passive observation. You can notice different methods of handling the plane employed by the teacher: e.g., the way to take off, the throttling of the motor when the plane levels off after the climb, as well as his use of the stick and the rudder-bar.

Certain conditions of the plane itself are noteworthy. You will remark the position of the nose in relation to the horizon. When the nose appears to sink below the sky line, it is in a glide; when

FIG. 33. FLY FAST!

This gruesome spectacle is one the student should have in his mind. Carelessness may mean a stall. A stall may mean a spin. A spin may mean a crash. A crash may mean a fire. And that may mean the end. Keep flying speed! Fly fast!

rising above the line, it is climbing. Study the manner in which the pilot makes a turn. Just as in bicycle riding it is necessary to lean to one side in going round a corner, so you must lean, or "bank," your plane toward the center of the curve which you are about to make. (See Figure 32.)

Since speed is what sustains flight, it is extremely necessary that you be impressed with the need for it; you must never lose flying speed. The instant the velocity decreases so that the force of gravity overcomes the lift of the wings, the ship goes into a

stall, and thence, unless expertly controlled, into a tail spin to the ground. The pilot has no better motto than "Keep Flying Speed." When in doubt, *Fly Fast!* (See Figure 33.)

The "feel" of the controls affords the safest means of judging speed. If the controls are lost ("go out"), the pilot is assured that he is not maintaining high enough speed. When the controls are soft and "mushy," and the plane does not respond quickly to their action, they are on the verge of "going out."

Length of Flight. The duration of the initial flight is usually something less than an hour. As much can be brought to your attention in that amount of time as you can readily assimilate; any further continuation of the flight would be comparatively fruitless.

Importance of Initial Instruction. The elementary instruction has a threefold importance. First, it is imperative that the beginner start correctly. Any flying habits which you acquire in your first lessons are likely to cling to you, be they good or bad. It is, then, most essential that the instructor point out all mistakes, that you may avoid them.

In the second place, early instruction is intended to accustom you to the "feel" of the plane. Before an aviator is truly proficient he must learn to fly by instinct. From the outset you must learn the "feel" of the controls, during each different maneuver. It is best that you ascertain by "feel" whether or not the speed is sufficient, just what position the plane is taking, and whether or not its balance is correct.

The first flight has the further purpose of giving you confidence. The beginner in aviation should soon get over the feeling that he is entering the unknown. The explanation made before the initial flight makes you realize that the control of the plane is by no means complicated. If your first lessons are short, and if you master each phase of flying step by step, you ought to acquire full confidence in your powers to manage a plane.

The forces which support the plane in the air are not mysterious and untried. Indeed, they are as certain and as concrete as the laws which hold a car on the road.

* * * * * * * *

As soon as you have finished your first flight, you should begin to keep a log. A pilot's log is filled out at the end of every day on which he makes any flights. In it he gives details of the duration and distance of the flights he has made, of the weather conditions, of the maneuvers which he practiced, and any other things which he considers of interest. A blank page from a log is shown in Figure 34.

PILOT'S LOG

NAME _____

ADDRESS _____

CLASSIFICATION _____ LICENSE No. _____

Date	No. of Flights	Time in Air	Distance Flown	Reg. Mark or Type of Plane Used	Nature of Flights	Certified by
Brought Forward						
Carried Forward						

Fig. 34. Blank Page from a Pilot's Log

Every pilot should keep a log recording the distance, duration, and other factors of interest concerning his flights.

SUGGESTIONS FOR READING ON PRELIMINARY FLIGHTS

Swoffer, Frank A., *Learning to Fly*, chap. II. Pitman.
Jones, Byron Q., *Practical Flying*, chap. XVIII. Ronald.
Studley, Barrett, *How to Fly*, chap. IX. Macmillan.

Questions for Review

1. Outline the subjects of ground school work, and explain their coordination with air work.

2. What is the purpose of preliminary flights? What benefits do you expect to gain therefrom?

3. Consult a transport pilot as to the kind, amount, and cost of clothing which you will need for your early training.

4. What duties are performed before an airplane leaves the ground?

5. If dual control is used for teaching airplane flight, why is it not equally applicable to teaching automobile driving?

6. Sit in the cockpit of an airplane. Can you imagine its movements, as you move the stick and rudder bar? Can you imagine yourself as a bird, with muscular command of the control surfaces?

7. What is the importance of preliminary instruction?

8. Interview three people as to the impressions they received on the occasion of their first flight. What lessons do their experiences teach you?

9. Write an article of 1,000 words on The Air as a Roadway.

10. Prepare for use in your own notebook a log form, with spaces for records which you consider pertinent.

CHAPTER V

ELEMENTS OF AERODYNAMIC THEORY

No intelligent flying is possible without at least a smattering of aerodynamics, which is the study of the air and of solid bodies moving through it. On the other hand, the average student pilot does not need to go deeply into the subject, which calls into play higher mathematics. He should know the mechanical effect of the air on the lifting surfaces of the plane, and how lift is affected by propeller thrust. He should know also why the rudder, ailerons, and elevators affect the stability of the plane and how they direct its movements. He should understand the effect of speed, load, and resistance on the flight of the plane. Above all, he should realize that *speed alone* enables the plane to overcome the pull of gravity. When speed is lost the plane stalls—and falls. When in doubt what to do, fly fast!

The Air or Atmosphere. The atmosphere, as everyone knows, surrounds the earth completely. This envelope consists of air. Air is composed chiefly of oxygen and nitrogen, with other gases in small proportions. Air has weight, and is affected by the force of gravity. The upper portions of the atmosphere weigh down upon the lower portions, hence the density of the air is greatest at sea level, where the approximate pressure of the atmosphere is 14.7 pounds per square inch.

Air is a fluid. It differs from a liquid in that it is easily compressed, and it is much lighter. Air has a tendency to fill whatever space is open to it, and will do so until the pressure inside the space is equal to the pressure outside. Also, since it has mass, an expenditure of force is necessary to move air. When displaced, the air has a tendency to spring back to its original position.

The Airfoil. An airfoil is a solid body designed to be projected through the air in order to produce a useful reaction. If a

very thin flat plate is passed through the air so that its surface is exactly in line with its path of motion, it will not disturb the air (leaving surface friction out of account) and will encounter no resistance.

If a rectangular flat plate is passed through the air so that its surface at the upper edge is inclined toward the direction of motion, it will, as it moves forward, force downward the air which it encounters. This causes a pressure on the lower side of the plate, due to the tendency of the air to resist compression and to regain its original position.

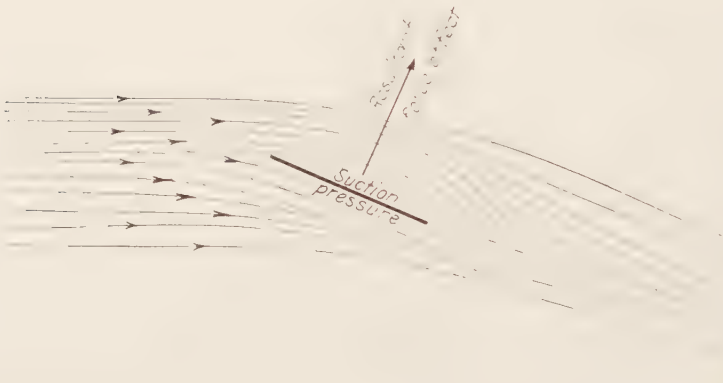


Fig. 35. A Flat Plate Airfoil

This shows the area of suction on back of plate and area of pressure on bottom of plate. Both of these combine to produce the effect of a lifting force perpendicular to the plate.

At the same time, the air behind and above the plate tends to follow and to fill in the space behind the plate. This following action of the air is relatively slow. Due to this lag, the result is a partial vacuum immediately behind the plate. This has the effect of a force acting perpendicular to the plate at its center, tending to pull it upward and backward. (See Figure 35.)

Streamlines. For purpose of study, it is sometimes preferable to reverse this process, and to consider the airfoil as stationary and the air as moving past it. Air, as it passes a body, has a tendency to follow certain lines. These are known as stream-

lines. (See Figure 36.) It is by studying the acting air as it passes around solids that the design of airfoils is perfected. The shape of airfoils should be such as to make the streamlines as

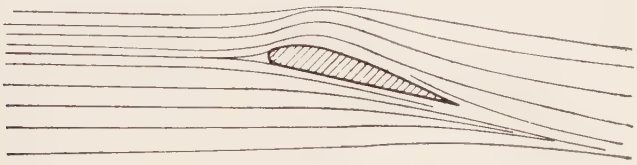


FIG. 36. STREAMLINE FLOW

As air passes a solid body, it diverges, and follows a certain path. This path is marked by streamlines. Airfoils should produce a smooth streamline flow.

smooth and regular as possible. Airfoils should also be designed so that their tendency to be lifted upward, while they are being forced forward through the air, is as great as possible.

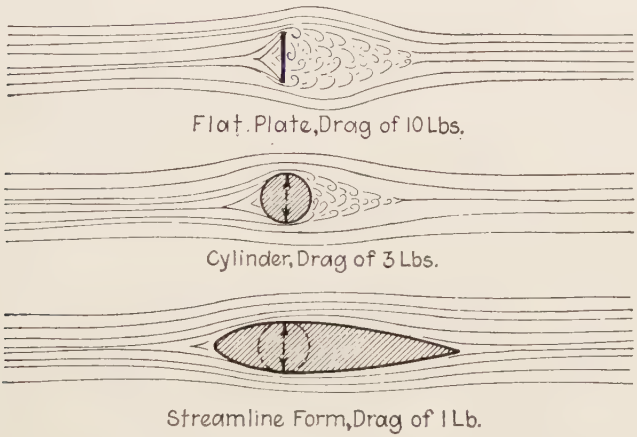


FIG. 37. RESISTANCE OF DIFFERENT SHAPES TO AIRFLOW

This shows airflow around different bodies and the approximate values of drag where they have the same diameter.

Parasite Resistance. The resistance of parts of the airplane which do not actually produce lift is known as parasite resistance. The object of the designer is, of course, to keep this resistance

as low as possible; hence such parts as the fuselage are modeled so as to have a good streamline form. This permits their easy passage through the air. Wing resistance plus parasite resistance make up the total resistance of the airplane.

Parasite resistance increases in proportion to the square of the air speed. Flat surfaces set at right angles to the air stream offer a great deal of parasite resistance, about ten times as much

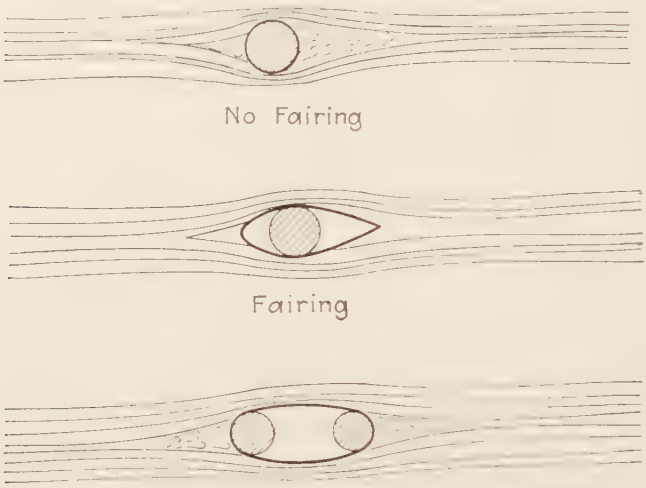


FIG. 38. FAIRING

A tube or wire causes considerable turbulence in the air. By the addition of wood or other material, it may be given a better streamline shape, and thus present less resistance to the air.

as a streamlined form of equal cross-section. Even cylindrical forms, such as round wires and tubes, add a great deal of resistance. (See Figure 37.) But if the bracing wires, struts, and fuselage are made with streamline sections, or as close to it as possible, their resistance is much reduced. If wires, for example, cannot be made in streamline form, the space between them may be filled in with wood or other material, and in this way a rough streamline shape may be obtained. This process is known as *fairing*. (See Figure 38.)

The fuselage cannot, of course, be made to conform exactly to the most efficient streamline form; but any angularities of the surface, at least, must be avoided. (See Figure 39.) Practical difficulties interfere with the attempt to reduce the parasite resistance of the fuselage below a certain point. An open cockpit offers considerable resistance, but a closed cockpit has many disadvantages. If the fuselage is large, so that crew and load may be accommodated, then the overall size goes up and resistance is

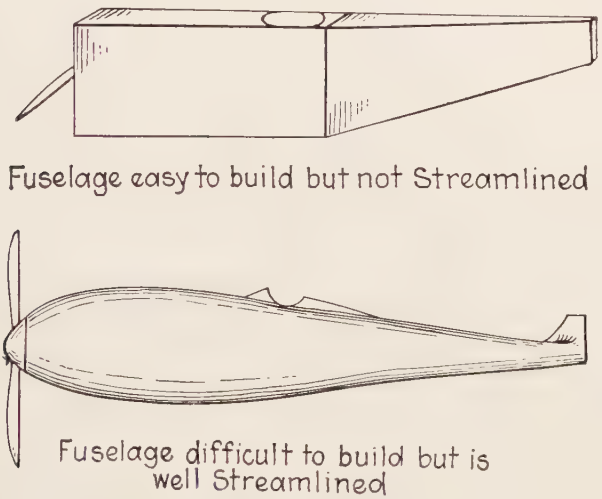


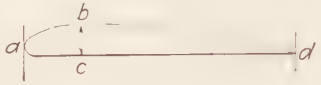
FIG. 39. STREAMLINING THE FUSELAGE

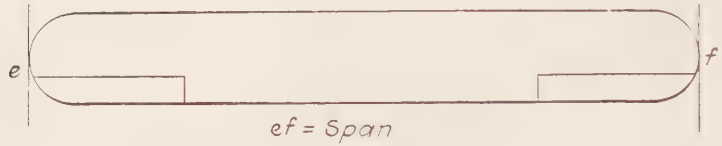
Many practical considerations militate against giving the fuselage a true streamline form. Even today, few ships have as low a parasite resistance as is desirable.

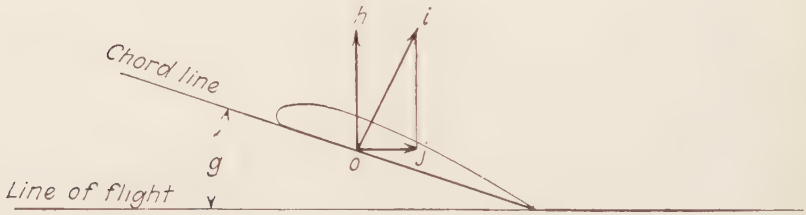
again increased. An air-cooled engine offers a good deal of resistance with its cylinders, while a water-cooled engine has a radiator which disturbs the streamline flow.

If the fuselage were to be made in perfect streamline shape, it should come to a feather edge at the rear; but this is not possible because of the necessity of attaching tail surfaces so that they will be held firmly. No entirely satisfactory method has been found of eliminating the parasite resistance of the wheels, although attempts have been made to design a plane whose landing

gear could be retracted into the fuselage after the plane has taken off.







g Indicates angle of attack
"oh" " lift
"oj" " drag
"oi" " resultant of both lift and drag
"o" " center of pressure
"oji" " lift, drag, and resultant triangle; where "j i" is drawn equal to "oh" and connects ends of resultant and drag lines. Always a right-angled triangle so that if any two sides are known the other may be easily found

FIG. 40. TERMS RELATING TO WINGS

It is important to memorize these elementary definitions, since they are constantly used in aviation.

Wings. Certain terms in regard to wings should be understood before going further. (See Figure 40.)

Lift is the force exerted upon the wing perpendicular to its direction of motion through the air. In other words, it is the force which supports the weight of the plane. Lift varies with speed; also with the angle of attack.

Drag is the resistance which the wing encounters in its passage through the air.

The resultant is a force acting upward and backward, and represents the total force exerted upon the wing. Lift, drag, and resultant may be represented graphically in a parallelogram of forces.

Angle of attack is the angle between the direction of motion and the chord of the wing.

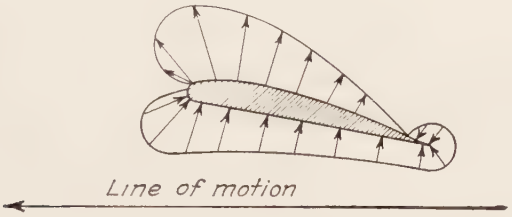


FIG. 41. FORCES ACTING ON AN AIRFOIL

The arrows indicate the direction and magnitude of these forces. It will be noted that the forces acting upward from the upper camber are even greater in the aggregate than those acting on the lower surface.

Angle of incidence is the angle between the chord of the wing and the line of thrust of the propeller.

Center of pressure is that point at which the resultant intersects the chord. It changes position every time the angle of attack is changed.

Historical Development of Wing Sections. In designing wings or airfoils, the objective is to get as much upward lift as possible with the least resistance to the forward motion of the wing. An improvement by early experimenters was the change from flat plate to streamline section. This reduced to a minimum the turbulence above the wing, with consequent decrease in drag.

The ancient, and still somewhat common, idea was that the greater part of the lifting effect of the wing was derived from the pressure against the lower surface; but experiment shows that

an average of 60 to 70 per cent of the lift is derived from the partial vacuum above the wing, as shown in Figure 41.

Figure 42 shows the path of the air around the modern wing section. It will be seen that only a part of the air is pushed down-

Fig. 42. Path of Air Around a Wing Section

This shows how air is deflected upward sharply by the contour of the front part of the wing. More air is being pushed upward than is being deflected downward.

ward, causing pressure on the lower side of the wing, while the front of the top curvature of the wing is very steep, and deflects the air sharply upward, so that it curves well away from the upper surface of the wing, and thus produces greater suction than the old-fashioned thin wing.

Fig. 43. Air Currents at the Wing Tip

Diagram of wing, as seen from the front, showing how air swirls up around tip of wing and reduces the pressure on the under side of the wing, as well as the vacuum on the upper side of the wing.

The Shape of the Wing. The thickness of the wing may vary from 5 to 20 per cent of its chord. (See Figure 40.) The ratio of its span to its chord (aspect ratio) is important, due to the fact that air from below the wing curls up around the end of the wing, tending to reduce the vacuum on the top surface of the outer portion of the wing. (See Figure 43.) Wings are often tapered

to minimize this difficulty. Within certain technical limits, a tapered wing is most efficient of any. Usually a wing is 5 to 8 times as long as it is wide. (See Figure 44.)

Lift and Drag. The lift and drag of a wing are calculated so that it will support the plane in level flight at the proposed

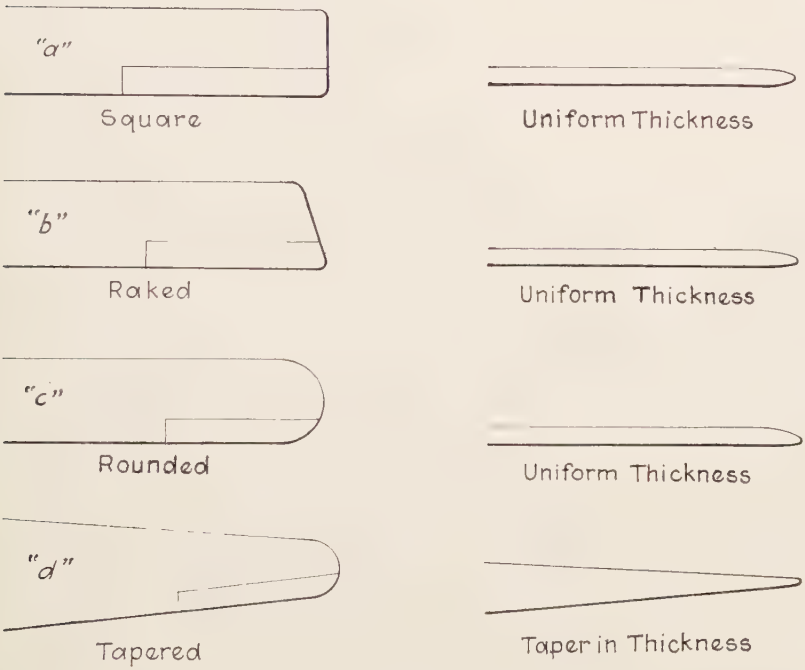


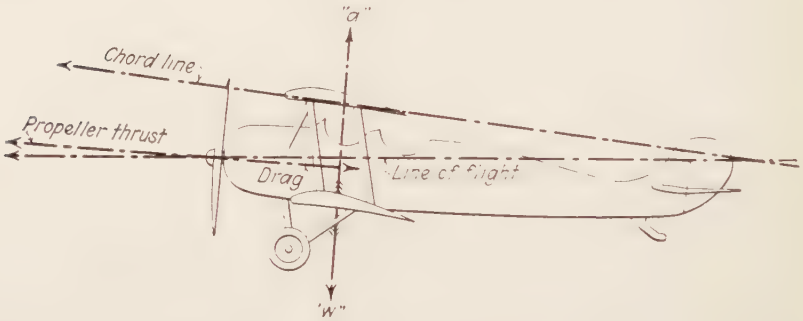
FIG. 44. FORMS OF WINGS

Of the four types illustrated, the lower two are the most common, because they are most efficient. The tapered tip is more efficient than the rounded tip, but is more expensive to build.

cruising speed. (See Figure 45.) Under normal conditions, the lift of a wing is directly proportional to its area. The shape of the wing, however, plays such a part that this statement is modified in actual practice. A properly designed wing, with efficient cambers, will lift more than a poorly designed wing of greater area.

Lift also increases as the angle of attack increases. At an angle of about 15 degrees (depending upon the particular wing) the lift suddenly begins to lessen. The angle at which this sudden reduction in lift occurs, is known as the "critical" or "stalling" angle, also as the "burble point." (See Figure 46.) The cause of this sudden decrease in lift is that the smooth streamline flow over the top of the wing has been broken, and the vacuum effect greatly diminished.

The drag also increases with the increase of the angle of attack. But at the stalling angle, the drag (unlike the lift) does not



Angle of attack = angle between chord line and line of flight
Angle of incidence = angle between chord line and propeller thrust

Fig. 45. Lift and Drag Versus Weight and Thrust

The plane is shown in level flight. Lift, indicated by "a" is equal and opposite to the weight of the plane, indicated by "w."

diminish. In fact, it becomes excessive. Beyond the critical angle the wing is but little more efficient than a flat plate. Up to the time the stalling angle is reached, the lift and drag increase approximately as the square of the speed, i.e., to double the speed will approximately quadruple the lift and drag.

The ratio of lift to drag is an important factor in designing wings, and is a direct measure of the efficiency of the wing. This ratio varies in different planes. A wing built for a commercial plane would be inefficient on a pursuit plane. The angle of

attack at which the lift is greatest in proportion to drag is usually about 3 to 6 degrees.

It should be remembered that the lift of the plane will decrease with the altitude, because the density of the air varies in inverse ratio to altitude. The lift of a plane at high altitude is much less than it is at sea level, with the same speed and angle of attack.

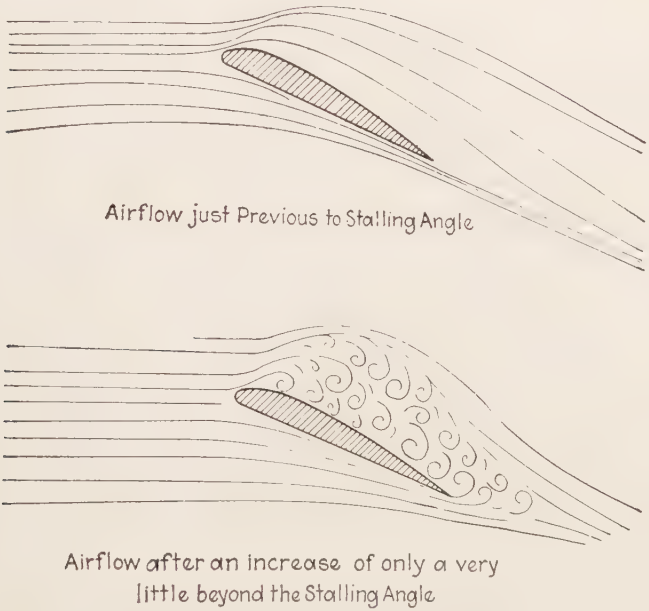


FIG. 46. THE STALLING ANGLE

A slight increase in the angle of attack brings the plane from its angle of highest lift to an angle of very little lift. It is at this point that the stall occurs. Fly Fast!

Devices for Increasing Lift at Low Speeds. Designers are constantly trying to work out methods of increasing the lift of wings at slow speeds. Attempts have been made to use flaps on the trailing edges of wings, and sometimes on their leading edge, which could be adjusted during flight; but they have not yet proved successful. (See Figure 47.) The mechanism to operate the flaps adds considerable weight. Also, there is danger

that the flaps will fail to operate at a critical moment. Again, they make the plane harder to control. They do, however, allow it to fly slowly, and to glide steeply without gaining much speed. This permits a much slower landing.

The slotted wing has proved a more satisfactory expedient. It consists of a small airfoil pivoted in front of the leading edge of the wing. In normal flight, the slot between the wing and this auxiliary airfoil is closed; but as soon as additional lift is required, the slot opens. The auxiliary airfoil is so designed that the air which rushes through the gap from below travels along the upper surface of the wing. This allows the plane to travel at a greater angle of attack, since the streamline flow of air does not break into eddies as soon as it normally would when the burble

FIG. 47. FLAPS ON THE WING

Flap on front edge of wing is so made as to be bent down and give the effect of more camber.

point is reached. The slotted wing allows a much lower flying speed; but it adds to the weight of the plane, and the additional drag, even when the slot is closed, prevents an equally high maximum speed. Furthermore, the wheels must be extended farther downward from the fuselage than in a plane with ordinary wings, otherwise the tail would strike the ground first in landing. This adds somewhat to the parasite resistance and to the weight of the ship. (See Figure 48.)

The automatic slotted wing has been used extensively, and with marked success, particularly on English planes. This wing slot opens itself without assistance from the pilot whenever the angle of attack comes too near the stalling point.

Combinations of Wings. A monoplane obtains greater efficiency from its wing area than a biplane, not only because there are no struts or bracing to increase resistance, but also because it has the maximum lift from suction. In a biplane (and, even more

so, in a triplane), the wing surfaces necessarily interfere with each other's functions. The pressure on the lower surface of the upper wing and the suction on the upper surface of the lower wing are reduced, so that the lift is decreased while the drag is increased. The most serious objection is the loss of suction on the upper camber of the lower wing.

A biplane can be braced more effectively than a monoplane, and this makes for lightness and strength. Also, the wing spread

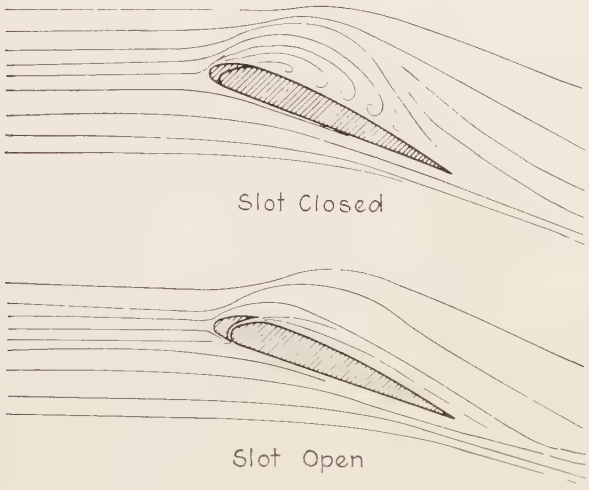


FIG. 48. DIAGRAM OF SLOTTED WING

Near the stalling point, the slot is opened and air is permitted to press from the lower surface to the upper surface of the wing. This increases the lift at low speeds.

of a biplane is naturally much less than that of a monoplane of equal wing area. This means that it requires less hangar space.

The Propeller. The propeller is a special type of airfoil. In contradistinction to the wing, it travels in a circular path, with the result that the tip of the airfoil travels at a much greater velocity and a much greater distance than its inner portions.

The airplane propeller is a screw, or helix, with two or more blades, which acts in the air much as a marine propeller acts in the water. The arms of the propeller are called the "blades," while

the central portion is known as the "boss," or "hub." The propeller is usually mounted at the front end of the fuselage, and drives backwards a cone of air called the slipstream. This current of air, acting on the elevators and rudder, increases their efficiency. Considering the propeller as an airfoil, the lift is the total force exerted parallel to the propeller shaft, and is called "thrust." The drag is the resistance which the propeller encounters in its revolutions through the air. (See Figure 49.) The pitch is the distance in line with the crankshaft which the propeller would travel in one complete revolution if it were to cut its way through a solid.

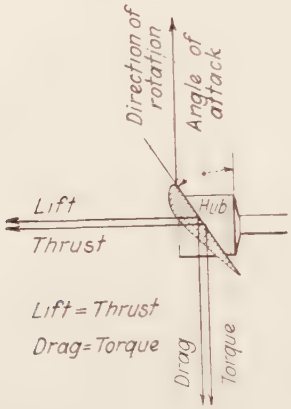


FIG. 49. AERODYNAMICS OF THE PROPELLER

Showing the similarity of forces which act upon a wing and upon a propeller. Lift is the equivalent of thrust; drag is the equivalent of torque.

Like a wing, a propeller is most efficient under only one set of conditions. It is designed to produce a given thrust, at a specified number of revolutions per minute, at a given speed of the plane, and for a given engine. The so-called load face, or the side of the blade which strikes the air first, is flattened, while the other face is curved. The two faces are comparable to the lower and upper surfaces of a wing. It is possible to calculate in advance the approximate lift and drag of a given propeller blade, with the result that the thrust provided by this propeller and the power necessary to rotate it at the desired speed may also be known.

Since the blades of the propeller interfere with each other, however, much as the upper and lower wings of a biplane do, and since a whirling motion is imparted to the air ahead of the propeller, the problem of making such calculations is a complicated one.

The efficiency of a large and slowly moving slipstream is greater than that of a small, rapidly moving slipstream. The propeller diameter should, therefore, be ample. It is interesting to remember that the slipstream is really shaped like a hollow cylinder, as the center of the propeller gives no thrust.

The efficiency of a propeller is measured by the lift-drag ratio of the blades, when operated under specified conditions. In order to develop propellers which will have the greatest efficiencies with different loads, at different altitudes, and for cases where the thrust must be great, as in climbing, variable-angled propellers have been developed, by which the angle of the propeller blades can be changed during flight by the pilot. They are still, however, in a developmental stage, and present serious difficulties of construction.

Engine Power. For an airplane in flight, power is only one of the elements of performance. Each performance factor is related closely to some other factor or group of factors. The angle of attack, for example, in level flight depends on the speed of the plane. So also does the drag. Speed, in turn, depends upon available power. A change in weight of the airplane affects all these factors.

Effective power is dependent only partially on the engine, because much of it is due to the efficiency of the propeller. The size of the propeller used will depend upon the available power of the engine. To increase engine power there must be an increase in its cubic capacity, its speed, or its overall efficiency. An increase in engine power permits using a propeller of greater lift, drag, and speed. The object, however, is to keep the weight of the engine as low as possible; hence, airplane engines are designed to run at high speeds, limited ordinarily by the speed at which the propeller can revolve efficiently. In some designs, the engine is run at high speeds while the propeller is geared down, so that the blades do not rotate so rapidly. This permits the engine to

run at its most efficient speed, and the propeller at its most efficient speed.

Speed of an Airplane. The minimum speed of an airplane is the lowest speed which it can maintain in level flight and still be under control. Its maximum speed is the greatest air speed which it can attain in level flight. Flying speed is any speed at which the plane may be flown safely. Racing airplanes often have a maximum speed of three times the minimum, while in commercial airplanes the maximum may be no more than twice the minimum.

Power and speed are, of course, closely related. This relation is particularly important in climbing. In order to climb, the pilot must have excess power. The most economical speed for a given airplane varies with the weight and with the altitude. This speed can be determined only by careful testing.

Loads. The so-called load factor of an airplane varies with the use to which it is to be put. A commercial plane, which is designed for freight or passengers and is not called on to perform acrobatics (which cause special strains on the plane), has a load factor which is not especially high. A plane designed for military use, on the other hand, must be designed to stand tremendous loads or stresses in performing such maneuvers as a fast dive. The airplane designer is always seeking to attain strength and lightness without sacrificing one for the other.

Terms often heard in connection with the subject of load are "wing loading" and "power loading." Wing loading is the major factor in determining minimum speed, and is obtained by dividing the total weight of the plane by the wing area. It is customarily desirable to have wing loading fairly low, so that the minimum speed of the plane will be low enough to permit easy landing. Power loading is found by dividing the total weight by the engine power. If the power loading is low, that is, if the engine power is high in comparison to the weight of the plane, then the speed and climb of the airplane will be high also.

Stability. An inherently stable airplane is one which flies in normal attitude without use of the controls. Whenever its path is disturbed by a wind current it may be momentarily deflected from its course, but will eventually return to it. An unstable air-

plane is one which must be brought back to its course by the pilot. A stable airplane is less maneuverable than an unstable one.

Stability may be longitudinal, directional, or lateral. When the pilot sets the airplane for a straight course, it must fly with a constant angle of attack, it must not yaw from side to side, nor must it have a rolling movement in flight. (See Figure 50.) As a matter of fact, pitching, rolling, and yawing (particularly the two last) are so interrelated that it is usual for two or all of them to take place at the same time.

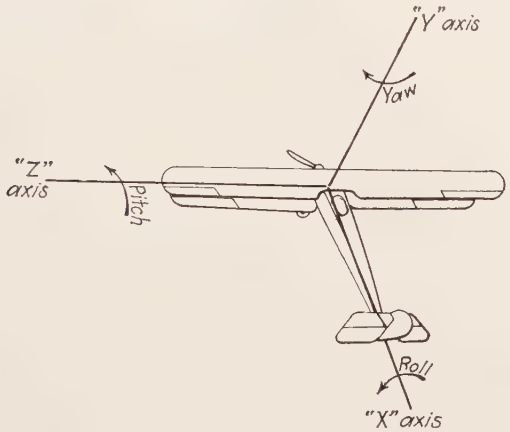


FIG. 50. AXES ABOUT WHICH THE PLANE MOVES IN FLIGHT

Motion about the longitudinal axis (x axis) is known as rolling. Motion about the lateral axis (y axis) is known as pitching. Motion about the vertical axis (z axis) is known as yawing.

Longitudinal stability cannot be secured by the wing surfaces alone, because these are unstable in gusts of wind. The result is the shifting, backward and forward, of the center of pressure. It is for this reason that the semi-fixed tail surface known as a stabilizer is placed on the plane. The stabilizer is designed in such a way that when the airplane is flying in normal position it helps to keep the plane in equilibrium. In normal horizontal flight, the stabilizer exerts little if any lift, but as soon as the nose of the plane rises, the stabilizer, being inclined, exerts a lift which brings the tail up and tends to level the plane.

In most planes, the stabilizer is made adjustable, in order to make corrections for shifts in the center of gravity, due to shifts in load. If the stabilizer is not adjustable, the elevators must be used to compensate for load. If the speed of the plane is increased above normal, it will normally start to climb and the elevators must be depressed, or the angle of attack of the stabilizer must be increased.

A plane which flies straight on its course, without turning to right or left (a practice known as yawing) is said to have *directional stability*. Yawing is overcome by the vertical tail surfaces, that is, by the fin and rudder. The fin is merely a fixed vertical airfoil, at right angles to the stabilizer. In fact, it is sometimes known as the vertical stabilizer. There is a tendency on the part of the plane itself to stop yawing, because, when yawing, the outer wing travels faster than the inner, giving it greater drag, and tending to correct the condition.

Under normal conditions, when the plane is flying straight ahead, the fin is at a zero angle of attack, but as soon as the plane starts to yaw the fin immediately cuts the airflow at an angle, and a force results which tends to push the tail back to its original position. If this automatic action is not sufficiently corrective, the rudder may be employed to increase the surface presented to the wind. Slight correction for torque may have to be more or less continuously applied; but this need does not indicate directional instability.

Lateral stability is gained, first of all, by the angle at which the wings are attached to the fuselage, so that they are properly balanced. Since the torque of the engine tends to throw the plane to one side, or roll it, the right wing is set at a slightly different angle from the left. In theory, an airplane should fly by itself and maintain its lateral balance in still air. This is accomplished by means of the dihedral angle of the wings, that is, by sloping the wings upward slightly on either side, instead of having them extend directly outward. The dihedral angle tends to overcome the sideslip which results from the rolling motion of the ship. The true angle of attack of the lower wing is greater in a slip than that of the high wing; hence, its lift is greater and it rises, thus correcting the roll.

If this automatic action of the dihedral angle is not sufficient, the ailerons must be employed. The action of the ailerons is such that when one moves up the other moves down. The result is that the lift of one wing is increased while on the opposite wing it is decreased, thus giving the ship a rolling motion.

Control. Stability of the three kinds just mentioned, is dependent upon the action of the three corresponding control surfaces, and these control surfaces are actuated by means of the

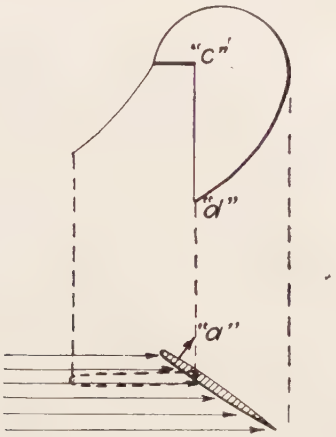


FIG. 51. BALANCED CONTROL SURFACE

In balanced types of control surfaces the air stream exerts a pressure on the front part of the control surface "a" which tends to assist the pilot in turning it.

The pilot supplies the difference between the force required to turn the main surface and the force supplied by the surfaces in front of the line "c-d."

stick and rudder, as set forth in detail in the chapter on Controls. The control surfaces, since they are required to change the position of the ship in the air, should be as powerful as is practical. They must be large enough to take effect forcibly at low speeds, especially when landing; but they must not be too large in area, otherwise too much strength will be required to operate them.

Various requirements have developed a variety of types of control surfaces. These may be classed as balanced or unbalanced.

On the balanced type of control, the air stream exerts sufficient pressure against a small section of the control surface which is forward of the line at which the surface is hinged. This reduces the amount of pressure which the pilot must exert. (See Figure 51.) The Frieze type of aileron is a kind of balanced aileron, being hinged near its center of pressure. (See Figure 52.)

Fig. 52. Frieze Type of Aileron

The Frieze type aileron has the effect of a balanced surface because the hinge is near the center of pressure. It is also more efficient because it is in reality a separate small airfoil.

Parts of a Plane. Figure 53 shows the parts of the airplane and the general constructional details. The parts may be grouped as follows:

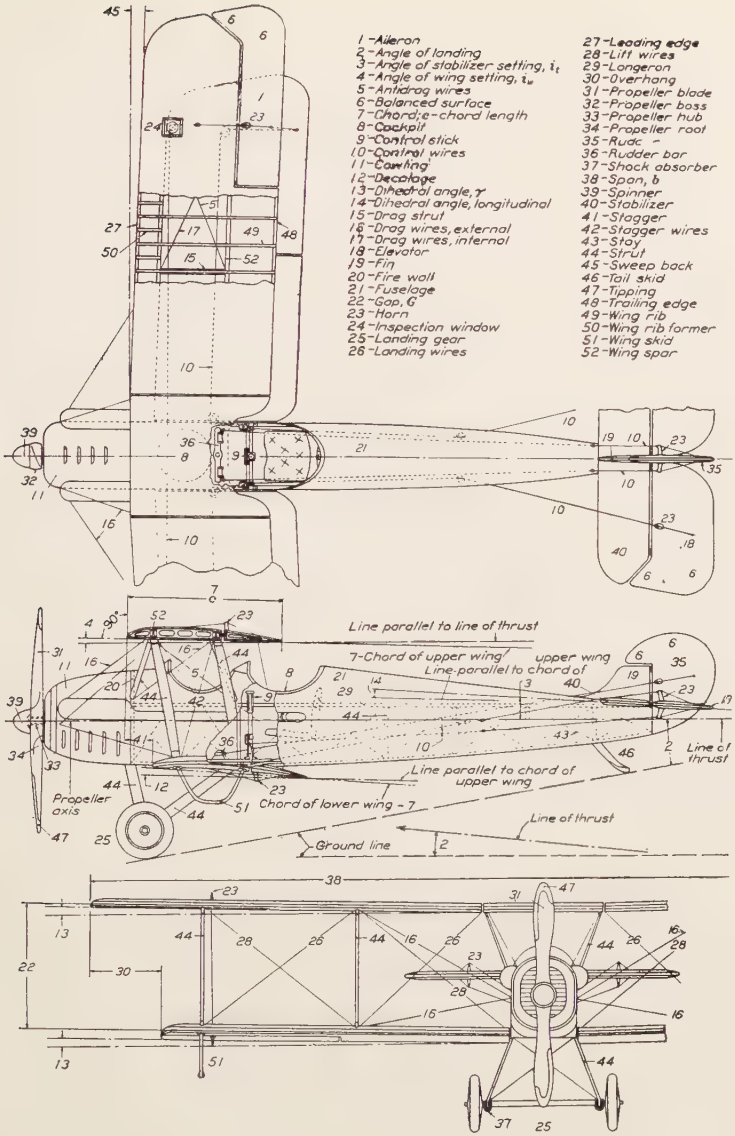
Supporting surfaces: wings and stabilizer.
Housing for parts not providing actual support: fuselage.
Power unit: engine and propeller.
Controlling devices: rudder, ailerons, elevators, stick, throttle, and rudder-bar.
Support when not flying: landing gear and tail skid.

* * * * * * * *

The parts of a plane above referred to are, of course, subject to variations necessitated by the special purposes for which a plane may be designed, but they are more or less typical. An examination of them will lead to an understanding of their interrelated functions. Such a study will be of inestimable value in acquiring the art of flight.

SUGGESTIONS FOR READING ON AERODYNAMICS

LePage, W. L., *A. B. C. of Flight,* chaps. I, II. Wiley.
Chatfield and Taylor, *The Airplane and Its Engine,* chaps. I, II, III, IV, V. McGraw-Hill.



National Advisory Committee for Aeronautics

FIG. 53. PARTS OF AN AIRPLANE

This diagram gives the student an opportunity to observe, in coordinated form, the embodiment of the principles of aerodynamics, as they have been set forth in this chapter.

LIBRARY
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EXPOSITION PARK

MONTEITH, C. N., *Simple Aerodynamics and the Aeroplane*. Government Printing Office.

WARNER, EDWARD P., *Airplane Design Aerodynamics*, chaps. III, IV. McGraw-Hill.

KLEMIN, ALEXANDER, *If You Want to Fly*, chaps. III, IV. Coward-McCann.

QUESTIONS FOR REVIEW

1. Why is an understanding of aerodynamics necessary in learning to fly?
2. What is the definition of an airfoil? Is the fuselage an airfoil?
3. What are the aerodynamic terms relating to wings? What do they mean?
4. What is the relation between lift and drag? Is this relationship constant?
5. Describe means which are or might be used for increasing lift at slow speeds.
6. Interview a pilot as to the comparative merits of monoplanes and biplanes.
7. In what way is a propeller comparable to a pair of wings?
8. Discuss the aerodynamics of flying speed. What is the relationship between speed and load?
9. What are the three axes of an airplane? How is rotation about each controlled?
10. Discuss the advantages and limitations of inherent stability.

CHAPTER VI

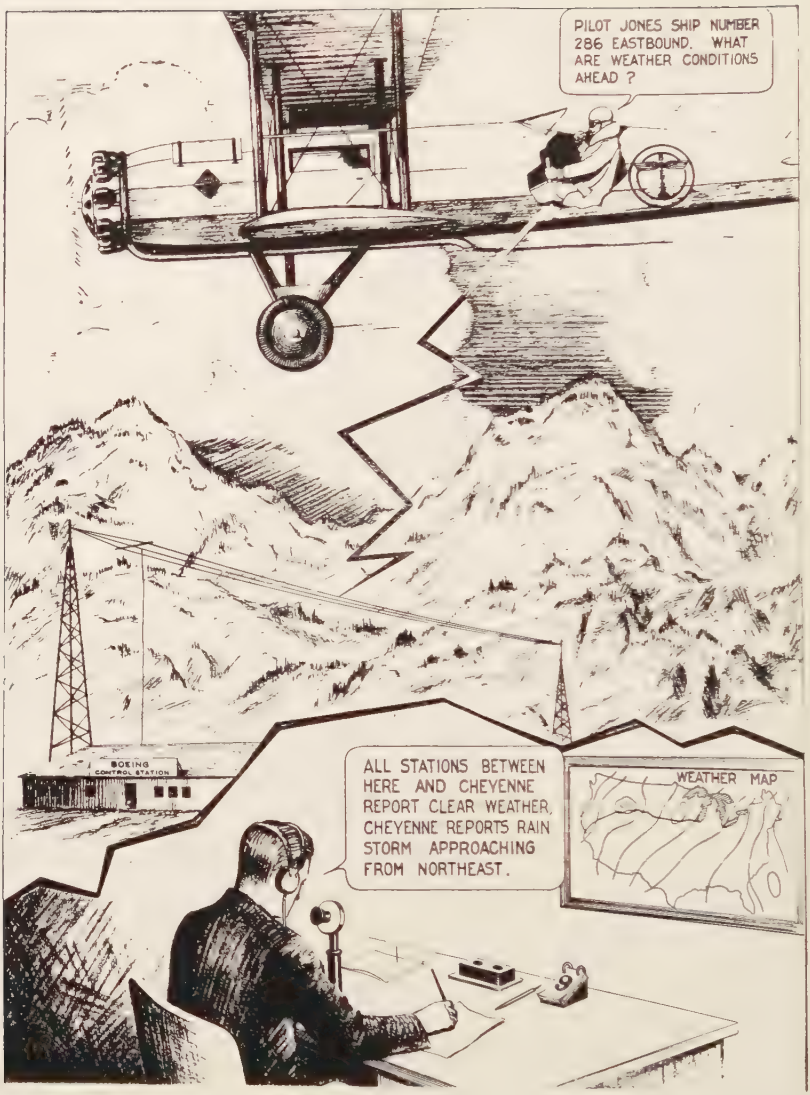
METEOROLOGY

Meteorology deals with the variations in the conditions of the atmosphere. It is a science of broad scope, which affects agriculture, marine service, insurance, and a great many other things, as well as aeronautics. The aeronautical branch of the subject, however, is now receiving much attention and has made great progress during the years since the war.

Advantages of a Knowledge of Meteorology. The prime advantage of meteorological information is to commercial airlines, in affording them the means of gaining the greatest efficiency in planning their schedules. Statistics have been compiled by the United States Weather Bureau showing the climatic conditions in the various regions of the country. By means of these data, the operators of mail and transport airlines can calculate, with a fair degree of accuracy, the average length of time in which planes can travel given routes.

Moreover, a knowledge of meteorology provides for greater safety in cross-country flights. The number of accidents due to weather conditions has been greatly reduced. Over two hundred stations have been established along the leading airways of the country, to furnish pilots with information. These stations, by means of their own observations, and by exchanging information with each other, are usually able to predict the state of the atmosphere, the wind direction and velocity, storm conditions, etc., for a few hours after the take-off of the plane. If any sudden change in weather conditions is threatened, these stations warn the pilot by means of a radio, as in Figure 54, or of signals made from the ground. The number of stations is rapidly increasing with the spread of aviation.

To the student himself, the technique of meteorology is of great academic interest, even though he may not often have occa-


PILOT JONES SHIP NUMBER 286 EASTBOUND. WHAT ARE WEATHER CONDITIONS AHEAD ?
BOEING CONTROL STATION
ALL STATIONS BETWEEN HERE AND CHEYENNE REPORT CLEAR WEATHER. CHEYENNE REPORTS RAIN STORM APPROACHING FROM NORTHEAST.
WEATHER MAP

Boeing Air Transport System

FIG. 54. ADVISING THE PILOT OF WEATHER CONDITIONS

By the use of radio, mail and transport pilots, when flying long distances, are able to know in advance what sort of weather conditions they will meet.

sion to put it into practical application. It is a subject of many complexities with which the student cannot expect to become familiar. But its general principles are simple, and it is important that he should know enough about it to predict the approach of any sudden change in weather conditions, and forecast in general the state of the atmosphere during the next 12 hours.

Elements of Meteorology. The average conditions of the atmosphere which prevail in a given region constitute its climate. The *specific* conditions which occur at a given time in a given region constitute weather.

The atmosphere is a gaseous substance surrounding the earth. With increasing altitude, the atmosphere becomes lighter, until, at a height of about 4 miles, the air is too thin to breathe. Three-fourths of the total amount of atmosphere is within 6 miles of the earth's surface. Normally there is also a corresponding decrease in temperature at the rate of about 3 degrees per 1,000 feet of altitude.

The changeable conditions of the atmosphere are described in certain terms which are standardized. These conditions are quite interdependent:

1. Wind direction and velocity, as recorded by wind vane and anemometer.
2. Atmospheric pressure, as recorded by a barometer.
3. Temperature, as recorded by a thermometer.
4. Humidity or moisture content and air visibility.
5. Cloud forms.
6. Precipitation, i.e., rain, snow, hail, etc.

These factors will now be discussed in detail.

Wind Direction and Velocity. In aviation, especial notice must be given to the present and probable condition of wind, visibility, and temperature.

The atmosphere is subject to motions (winds) which may be classified as primary and secondary. The primary motions are caused by the heating of the atmosphere by the sun and are given their peculiar direction by the rotation of the earth. Apart from the heating of the atmosphere by the sun, the rotation of the earth

would of itself cause a movement of the atmosphere. (See Figure 55.)

It is because of the rotation of the earth that the prevailing wind currents across the United States are westerly. These general wind currents are, however, diverted into other directions by irregularities which occur on the surface of the earth. At alti-

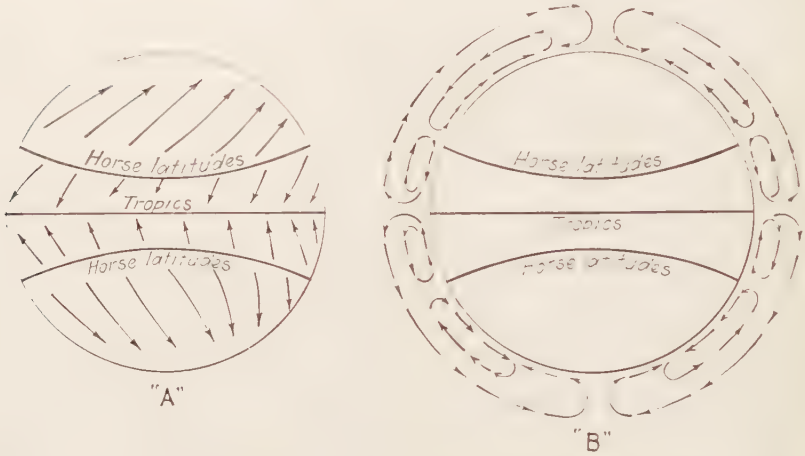


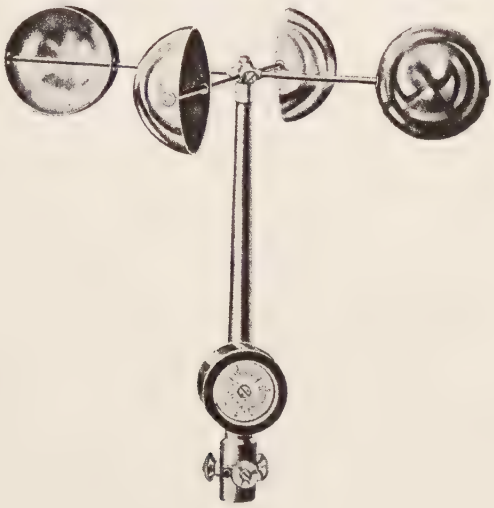
FIG. 55. PRIMARY MOVEMENTS OF THE ATMOSPHERE

A. Arrows indicate direction of those winds which are close to the surface of the earth. Where winds rush together, as at the equator, an upward motion must result as shown in B by the arrows. Where opposite winds depart from the same line there will be a downward rush of air which spreads out in both directions as at the "Horse Latitudes."

B. A cross-section of the winds showing, by arrows, the directions taken by the winds at high altitudes. Arrows show how air passes toward the poles at high altitudes and gets cooled sufficiently to drop to the surface of the earth and become a trade wind again, following this cycle of motion repeatedly.

tudes of 2,000 or 3,000 feet above the land, and of 1,000 or 2,000 feet above the sea, local irregularities have little effect on the primary motions of the atmosphere. For this reason, long flights are usually made at an altitude great enough so that the direction of the prevailing wind may be fairly constant, provided, of course, that this does not entail working against a strong head wind.

The velocity of the wind may be of extreme importance to the pilot, and this is measured constantly at all weather stations. Winds on the surface of the earth are measured by means of an anemometer. The best known type is the Robinson cup anemometer. (See Figure 56.) The hollow cups are made of thin copper or aluminum, and are nearly hemispherical in shape. They are at-



U. S. Weather Bureau

FIG. 56. AN ANEMOMETER

The faster the rate of the wind, the faster it revolves these cups. Their rotation is recorded on the dial. There is also an electrical device which records on a strip of paper the variations in wind velocity over a given period of time.

tached by arms to a spindle which is connected to a dial. The speed of the wind, by its effect in rotating the cups, is recorded on this dial.

"Winds aloft" are measured by sending up small balloons which ascend at a rate of speed known in advance. The horizontal drift of these balloons indicates the direction and velocity of the wind at that particular height; these are determined by taking sights on the balloon at measured intervals, through the use of an instrument not unlike a surveyor's theodolite, that is, a sort of

telescope, graduated to measure angles in both vertical and horizontal planes.

In the majority of cases, the pilot will not be able to obtain information about wind velocities soon enough to help him a

Directions for Estimating Velocity from Visible Effects of the Wind	Velocity Statute miles per hour	Terms used in U. S. Weather Bu. Reports
Calm, smoke rises vertically	Less than 1	Calm
Direction of wind shown by smoke drift, but not by wind vanes	1– 3	
Wind felt on face; leaves rustle; ordinary vane moved by wind	4– 7	Light
Leaves and small twigs in constant motion; wind extends light flag	8–12	Gentle
Raises dust and loose paper; small branches are moved	13–18	Moderate
Small trees in leaf begin to sway; crested wavelets form on inland waters	19–24	Fresh
Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty	25–31	Strong
Whole trees in motion; inconvenience felt in walking against wind	32–38	
Breaks twigs off trees, generally impedes progress	39–46	Gale
Slight structural damage occurs (chimney pots and slate removed)	47–54	
Trees uprooted; considerable structural damage occurs	55–63	Whole Gale
Rarely experienced; accompanied by widedamage	64–75	
	Above 75	Hurricane

Rand McNally & Company

Fig. 57. An Aid in Estimating Wind Velocities

Wind velocity is the rate, in statute miles per hour, at which the wind is blowing. The U. S. Weather Bureau uses the terms given above for reporting wind velocities. This table will be of considerable help in helping the pilot to estimate wind velocities.

great deal, and he must rely on his observation and judgment. Figure 57 gives him an idea of how to estimate the speed of the wind by the observation of familiar phenomena.

The secondary motions of the atmosphere, although subject to directional influence by the primary currents, are largely independent of them, and are, for the most part, local in nature, sel-

dom exerting their influence over a radius of more than a few hundred miles. These secondary motions are induced by changes of pressure and temperature, but are modified by the contour of the terrain, such as mountains and valleys. Secondary motions of the atmosphere have a direct relation to areas of low pressure and to those of high pressure.

Pressure. The presence of "high" and "low" pressure areas is indicated by the barometer, a fairly familiar instrument which records changes in atmospheric pressure. In general, a rise in the "glass" indicates improving weather conditions, a fall indicates that the weather is growing less favorable. If the rise or fall is rapid, a sudden change in the weather may be expected. If the barometer remains steady and the atmosphere is dry, the weather promises to remain fair.

High-pressure areas are invariably fair-weather areas and low-pressure areas usually produce cloudy weather, often with rain in certain parts. Weather is, to quite an extent, a matter of pressure areas. A lowering of the atmospheric pressure allows air to rush into this area from all sides, and this air ascends, with the result that an extensive area of cloud is formed by the resulting condensation of the moisture in the air, which cools as it rises. As a general rule, ascension of air results in condensation of the moisture it contains, while a reverse effect holds true where the air is descending, as in an area of high pressure. These low-pressure areas usually cover an extent of perhaps a thousand miles in diameter, with a calm spot in the center. In the United States, the rain and cloudy weather are usually found in the southeast section of the "low."

There are motions within these areas of high or low pressure which are of utmost importance in making local weather predictions. In a low-pressure area, the air rushes inward and upward in a counter-clockwise spiral. In a high-pressure area, being in every way the opposite of a "low," the air blows downward and outward in a clockwise spiral. (See Figure 58.)

High-pressure areas are usually called anti-cyclones and low-pressure areas are generally called cyclones. Cyclones and anti-cyclones are of various kinds. A tornado is merely a concentrated

cyclone of small area and extreme violence. A thunderstorm is the result of rising air which mushrooms out into the familiar thunderhead and continually gains size and speed. Tornadoes and thunderstorms are most dangerous due to their extreme violence, so that it sometimes becomes impossible to maintain stable flight in them. They should be avoided by landing or by flying the plane around the affected area. (See Figure 59.)

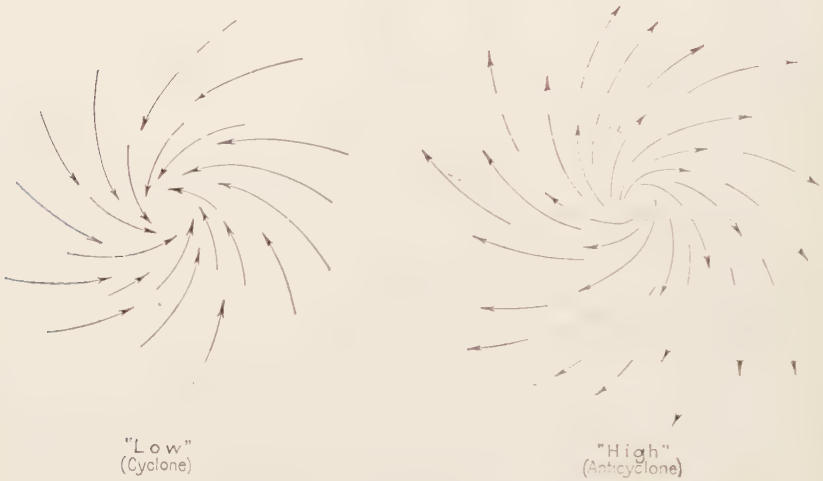


FIG. 58. CYCLONES AND ANTICYCLONES

Arrows indicate direction of wind moving in counter-clockwise spiral with an ascending current in the center. This is a cyclone ("Low"). Arrows indicate direction of wind moving downward and outward in clockwise spiral with a descending current in the center. This is an anticyclone ("High").

Temperature and Moisture. A lowered thermometer is usually of a greater significance to the pilot than a rising one. When the temperature of the air is below freezing point, there is great danger that snow or rain will form "ice barnacles" on the wings and struts of an airplane. The parasite resistance caused by these will, if continued, force the plane to land.

The moisture content of the air is a hindrance to flying whenever it reaches the point where fog is formed, since this shuts off the pilot's vision. The presence of moisture in the air has various

effects. When dew is forming, the weather is good. Fog forms when the earth's surface is cooled off enough to condense the contiguous moisture of the air. This usually occurs at night, when the air is quiet enough to allow the lower layers of the atmosphere to remain in contact with the earth long enough for their moisture to condense.

Cloud Formations. Clouds are formed when certain sections of the atmosphere are heated to a temperature above that of the

FIG. 59. THUNDERSTORM CURRENTS

This shows a cross-section showing the extremely rapid upward rush of air in the mushroom-shaped "thunderhead."

surrounding sections of air. The warmed air is lighter than the surrounding air, and rises. The atmospheric pressure becomes slighter, and the temperature lower, so that the moisture in the air condenses into clouds. There are several types of cloud formations, all more or less indicative of approaching conditions. Of these, the most threatening is the cumulus-nimbus, or thundercloud. This is a mound of heavy clouds, often rising from a sea of cumulus clouds. The cumulus cloud is shown in Figure 60.

Heavy rain usually falls from its base. Such clouds approach very fast, although they rarely cross large rivers. A pilot should always avoid them, either by landing, or by flying around them rather than over them, since they usually cover only a small area and extend upward to an inconvenient altitude.

Mare's tails, long streamers of cloud, across a clear sky, are normally signs of fair weather and wind. Formation of gray

FIG. 60. CUMULUS CLOUDS

These clouds appear to be formed by a diurnal ascensional movement which is almost always noticeable. True cumulus has well defined upper and lower limits, as here.

amorphous masses of cloud, covering a large part of the sky and completely blotting out the sun at sunset, is usually an unfavorable sign. In general, clear-cut clouds are indicative of strong winds, feathery white clouds of pleasant weather, and ragged gray clouds of rain.

The tints of the clouds at sunrise and sunset may be roughly used as weather indicators. A red sunset usually indicates fine

Pennsylvania Railroad and Transcontinental Air Transport, Inc.

FIG. 61. PLANE FLYING ABOVE CLOUDS

Clouds of this type (cumulus) are often encountered by the pilot. There are frequently spaces between such clouds through which the ground may be seen.

weather, and a yellow sunset either wind or rain. Gray clouds at sunrise forecast sunny weather, and red clouds wind and rain. Too much significance should not be attached to such signs.

The altitude of clouds is of extreme importance to the pilot, because of their effect on his visibility. A "low ceiling" means that the clouds are hanging very low and that he may have to do

Official Photograph, U. S. Navy

FIG. 62. FLYING ABOVE FOG

Fog may be considered simply as low lying clouds. It frequently forms near or over bodies of water, as here.

"blind flying" in them or fly high above them. Figure 61 shows a plane flying above a sea of clouds.

Precipitation. Rain is formed by the same process which produces clouds, but is carried to a greater extent, so that the globules of moisture, held in suspension by the atmosphere so as to form clouds, form drops too heavy to be supported. A rain is not of necessity dangerous for a pilot except as the lowered clouds interfere with visibility. Where the temperature is low

enough to freeze the rain on to the plane, or to turn the rain into snow or hail, however, it might cause him serious trouble.

Fog is caused by cooling a layer of air which lies close to the earth so that the moisture condenses into minute drops. In other words, fog is merely an extremely low cloud form. (See Figure 62.) It rarely forms more than a thin layer over the surface of the earth; but a few feet of fog can prevent a ship from landing. Fog is apt to be persistent over and in the immediate vicinity of bodies of water. The prediction of fog formation seems to be at present an unsolved problem.

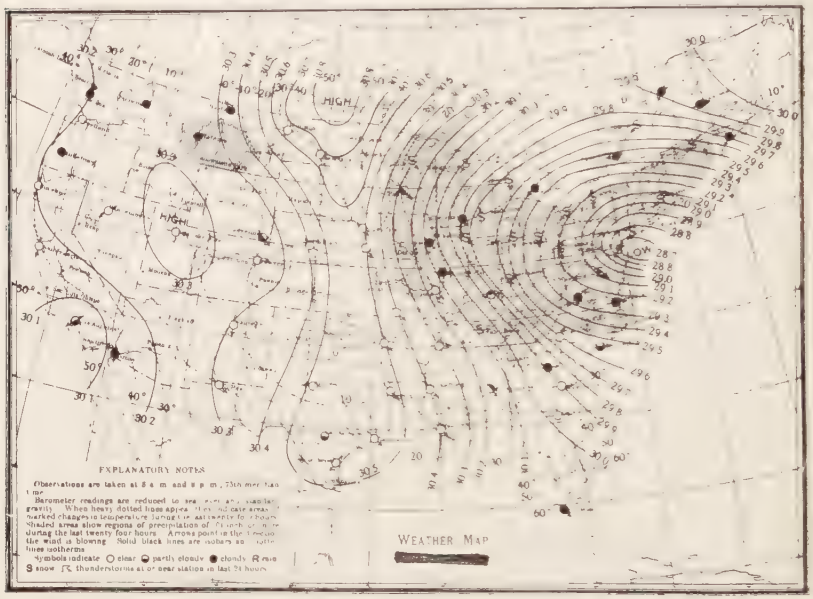
Weather Maps. The process of forecasting the weather has many ramifications, and requires considerable apparatus. Therefore, accurate judgments of the weather can be made only by observers properly equipped for the purpose. In order to provide people with data relating to the basic prevailing weather conditions, the Weather Bureau publishes daily weather maps.

A weather map shows the state of the atmosphere during the previous 24 hours. On these maps solid lines connect points having the same atmospheric pressure. The presence of high- and low-pressure areas is indicated by the words "high" and "low." Dotted lines are drawn through points having the same temperature. At each airline station (or government weather station) the direction of the local wind is designated by an arrow, and symbols show whether the weather was clear or stormy during the previous 24 hours. Areas where rain or snow fell are indicated by shading. (See Figure 63.)

By bearing in mind that "highs" and "lows" move slowly eastward (in this country) and that they are followed by the wind, and by allowing for the effect of local hills and bodies of water, forecasts for the next 24 hours can be made from these maps. This requires considerable experience and knowledge, however, hence the student pilot should not expect exact predictions.

Weather maps are especially important in planning any long-distance flight. In addition to the usual map for the previous 24-hour period, a great deal of information, useful in making the forecast, can be obtained by comparing successive maps and ob-

serving the progress of the "lows." Also the nearest weather bureau station can at specified times furnish a report of current conditions at any point where another station may be located, and will give an up-to-the-minute prediction.



U. S. Weather Bureau

FIG. 63. WEATHER MAP

"When the wind sets in from points between south and southeast and the barometer falls steadily, a storm is approaching from the west or northwest, and its center will pass near or to the north of the observer within twelve to twenty-four hours, with winds shifting to northwest by way of southwest and west. When the wind sets in from points between east and northeast, and the barometer falls steadily, a storm is approaching from the south or southwest, and its center will pass near or to the south of the observer within twelve to twenty-four hours, with winds shifting to northwest by way of north. The rapidity of the storm's approach and its intensity will be indicated by the rate and the amount of the fall in the barometer."

Weather Forecasts. Although exact forecasting requires experience and equipment, general prognostication for a period of 10 or 12 hours can be made by the average man from the conditions of the clouds, wind, and the barometer. Wind direction and

change, together with barometric change, will predict with considerable trustworthiness the coming conditions.

The following hints may be of value:

A falling barometer means that the center of the low pressure is approaching and the weather will be stormy.

To establish the direction the "low" is coming from, stand *back to the wind* and the center of low pressure will be 45 degrees to the left of the direction in which the observer faces. For example, a south wind and falling barometer mean a "low" is approaching from the northwest. When the wind changes, the direction of this "low" can again be taken and, combined with the barometric change, can be charted so as to show the direction in which the "low" is moving.

A "high" may be observed in exactly the reverse manner, that is, when one faces the wind the "high" area is 45 degrees to the left. The wind in a "high" is exactly reversed (see Figure 58) and the barometer rises as the "high" approaches. This indicates a period of fair weather.

The probable course of a "low" may be estimated with some degree of accuracy by noting its track during the previous 24 to 48 hours and by reference to map showing the usual paths of "lows" across United States. It should also be remembered that the southeast section of a "low" is apt to be stormy and the northwest section of it is likely to be clearing.

* * * * * * * * *

Weather seems to the average person to be a result of accidental circumstances, but meteorology is no "accidental" study. Weather conditions follow a prescribed atmospheric condition with mathematical certainty. The cause of weather is mysterious and uncertain to the uninitiated merely because they are unable to perceive or understand the relationship between the cause and the effect.

Meteorological instruments provide a means for studying weather phenomena and their relationships, so that anyone who wishes may get to understand in a general way how the atmosphere behaves and why. To the expert it presents a scientific

problem of infinite and fascinating variations, the mastery of which is of utmost value to commercial aviation.

SUGGESTIONS FOR READING ON METEOROLOGY

DUNCAN, *Air Navigation and Meteorology*, chaps. XII, XIII, XIV. Goodheart and Willcox.

YANCEY, L. A., *Aerial Navigation and Meteorology*, chap. IX. Henley.

GREGG, W. R., *Aeronautical Meteorology*, chap. I. Ronald.

WALDO, F., *Elementary Meteorology*, chap I. American Book Co.

QUESTIONS FOR REVIEW

1. Of what value is a consistent study of meteorology to a pilot?
2. Enumerate and explain the subjects which come under the heading of Meteorology.
3. What are the primary and secondary motions of the atmosphere? How is a knowledge of them useful in aviation?
4. How are wind velocities measured?
5. Explain how "highs" and "lows" affect the winds and the weather.
6. How does temperature affect precipitation?
7. Consult a practical pilot on so-called weather "signs" and their value.
8. Discuss with a pilot the problem of fog and how it should be dealt with by the aviator. Obtain information as to recent inventions for coping with fog.
9. Visit a Weather Bureau station and find out what methods are used for measuring meteorological phenomena and disseminating news about them.
10. Attempt, by using weather maps, to predict local weather, each day for one week.

CHAPTER VII

HOW THE CONTROLS ARE OPERATED

Fortunately, the instructor can make clear the subject of controls, even before the student receives any actual flight instruction. Great stress is laid on the functions and means of operating the controls, since no progress whatever can be made in the air until their use has been thoroughly mastered.

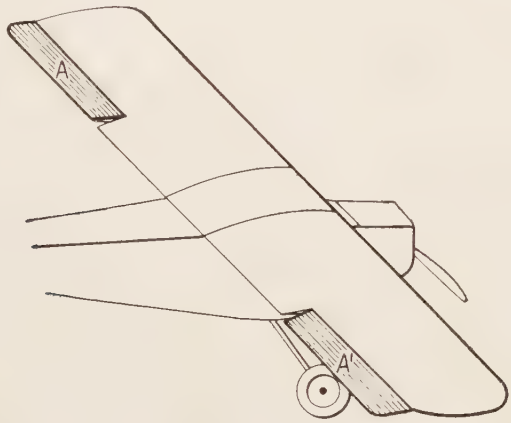


Fig. 64. How the Ailerons Are Operated

A and A^1 are the ailerons. They are interconnected in such a manner that when the left aileron is up, the right one is down, and *vice versa*. The ailerons are operated by the sidewise movement of the stick.

The controls are the mechanisms which regulate the movements of the plane. They may be divided into two groups, primary and secondary. In the first group are: the ailerons and the elevators, both of which are actuated by the stick, and the rudder, which is controlled by the rudder-bar. The secondary controls are the stabilizers, the throttle, and the brakes.

Ailerons. The ailerons are flaps hinged to the rear edges of the wings, either near their tips or (rarely) extended along their whole length. The ailerons control the lateral stability of the plane. (See Figure 64.) When the aileron on the right wing, for example, is lowered, the upward pressure of the air on that side is increased, and the right wing is raised. Since the left aileron

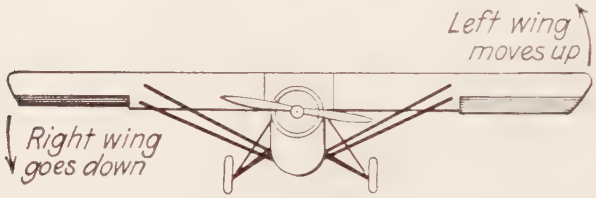


FIG. 65. ACTION OF THE AILERONS

When the left aileron (a) is lowered it presents its full surface to the air and increases the lift of the left wing. At the same time, the right aileron (b) is raised, and decreases the lift of the right wing.

is raised at the same time, the lifting force on that side is decreased, and the left wing is depressed. The opposite takes place when this action is reversed. (See Figure 65.)

Elevators. The elevators, or "flippers," cause the tail to move up and down, thus changing the longitudinal angle of the

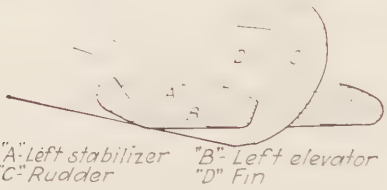


FIG. 66. THE TAIL ASSEMBLY

The elevators are hinged at the rear of the stabilizers. The rudder is hinged at the rear of the fin.

ship. The elevators are, in effect, one flap split into two to permit the swinging of the rudder, and both elevators always move as a single unit. They are hinged to the trailing edges of the horizontal surfaces known as stabilizers. (See Figure 66.) When the elevators are depressed, the lifting force on the tail surfaces is

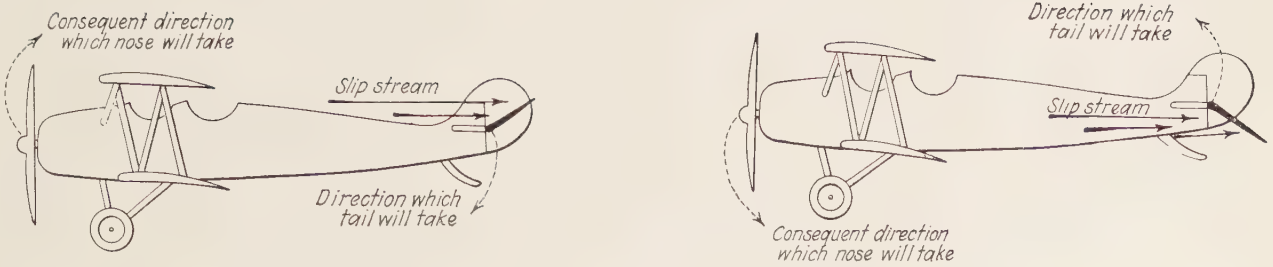
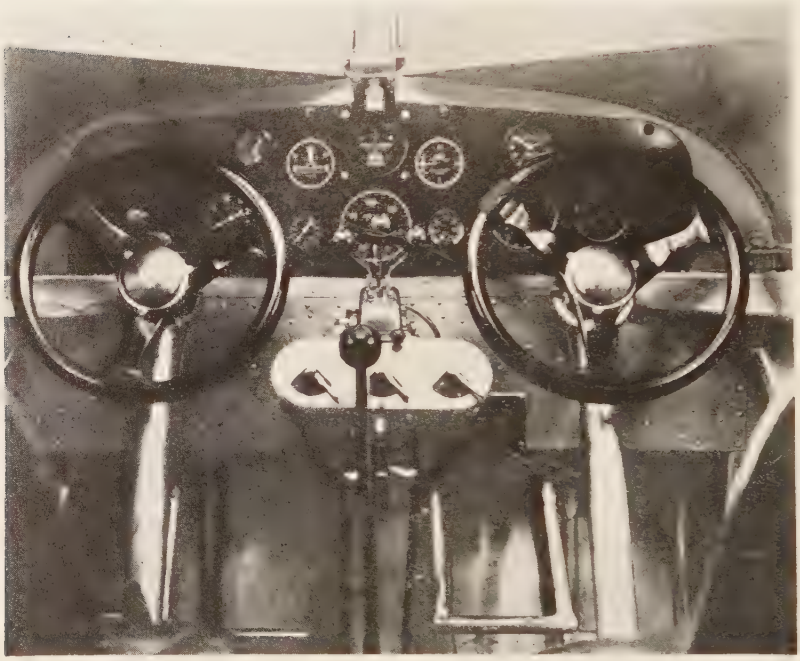

Consequent direction which nose will take
Slip stream
Direction which tail will take
Direction which tail will take
Slip stream
Consequent direction which nose will take

Fig. 67. Action of the Elevators

When the elevators are raised the pressure of the slipstream against them tends to depress the tail, and thus to elevate the nose. Lowering the elevators has the opposite effect.

increased, the tail rises, and the plane tends to go into a dive. When the elevators are raised, their angle of attack decreases, and their lifting force decreases, so that the tail sinks and the nose rises. (See Figure 67.)



Pennsylvania Railroad and Transcontinental Air Transport, Inc.

FIG. 68. DEPERDUSSIN CONTROL

This type of control, where wheels, instead of sticks, are used, is applicable to large planes, such as this one, which is a Ford Tri-motor. Turning the wheels (they both turn in unison) operates the ailerons. The elevators are operated by the forward and backward movement of the column to which the wheels are attached. Notice the rudder-bars: also the three switches for the three engines. The lever between the two pilots' seats operates the brakes.

The Stick. The stick has already been described as the lever in the cockpit which the pilot manipulates with his hand. The stick was originally called "Joyce stick" because it was invented by a man named Joyce. This appellation depreciated into "joy

stick," a name almost universally used during the war. Now it is usually called simply "the stick."

In large planes, the stick is often replaced by a Deperdussin wheel which is turned like an automobile wheel instead of being pushed from side to side to control the ailerons. The entire column is, however, moved forward and back like any other stick to control the elevators. (See Figure 68.) In flying parlance, the name Deperdussin has been abbreviated to "Dep." Some pilots mistook "Dep" for "depth," since the control regulates the depth or altitude of the plane, and "depth" also has become a common name.

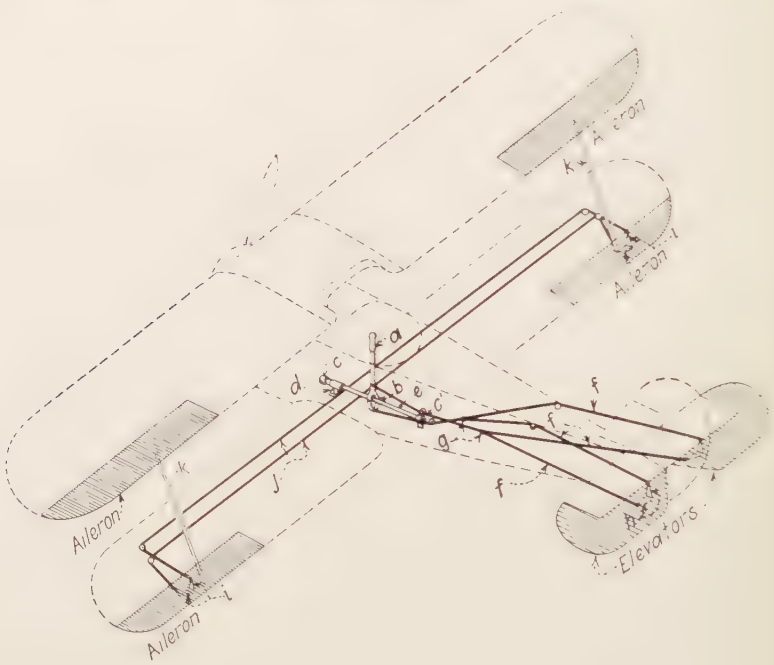
The stick has two functions: to roll the ship from side to side, and to raise and lower the nose. It accomplishes the first function by guiding the movements of the ailerons, the second by guiding the movements of the elevators. The wires which connect the stick with these control surfaces are shown in Figure 69. Observe how, when the stick is pushed to the left, for example, the left ailerons are raised, and the right ones lowered, to produce a dropping of the left wing. It is also clear that the stick (when pushed ahead) forces the elevators down, and raises them when pulled back.

The Rudder. The rudder determines directional stability. It is a flap swinging on a vertical axis, located at the rear end of the fuselage. It is hinged to the fin. The rudder is positioned between the two elevators. (See Figure 67.) If turned to the left, and thus set at an angle to the path of the plane, the force of the air on the rudder will then throw the tail to the right and the nose to the left. (See Figure 70.)

The Rudder-bar. The rudder-bar is located in the forward part of the cockpit and is worked by the pilot's feet. It is connected by wires to the rudder. Figure 69 shows how a forward push of the rudder-bar on one side will swing the rudder to that same side.

How to Handle the Primary Controls. At low speed, rudder, elevators, and ailerons are sluggish in action, and can be made effective only by rapid and vigorous movements of the rudder-bar and stick. But as the speed of the ship increases they become more sensitive and light pressure on the bar and stick is enough to operate them. (See Figure 71.)

Old pilots say that the handle of the stick should be regarded as an eggshell. The student's grip should be relaxed, and he must not "freeze" on to it. The controls should be moved deliberately



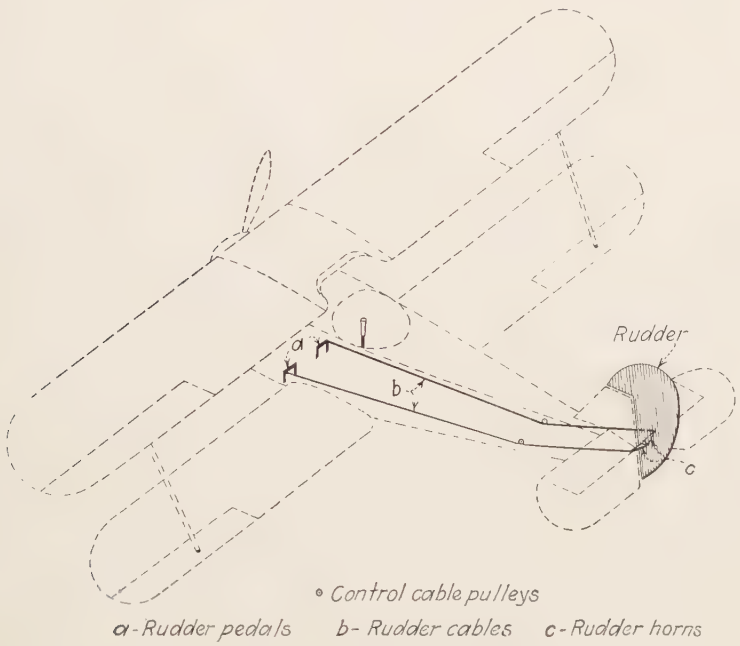
a - Stick
b - Pin joint
° Control cable pulleys
c,c' - Torque tube bearings
d - Sector for operating aileron cables
e - Torque tube
f - Elevator cables
g - Cable unions
h - Elevator horns
i - Aileron horns
j - Aileron cables
k - Strut to operate upper aileron

A

and slowly, in order to prevent the danger of "overcontrol," that is, the moving of one control too far, and, in correction of that error, moving it too quickly and too far in the opposite direction.

The skillful pilot seldom has occasion to make violent movements of the stick or rudder-bar.

Stabilizers. The stabilizers are horizontal surfaces projecting from the rear of the sides of the fuselage at either side of the rudder. (See Figure 67.) They afford a measure of longi-



B

FIG. 69. (A AND B). SYSTEM OF CONTROLS AND CONTROL SURFACES

These two drawings show the mechanisms whereby the ailerons and elevator are connected to the stick, and the rudder with the rudder-bar.

tudinal stability, serving as auxiliaries to the elevators, which are attached to their trailing edge. Their purpose is to make it easier to handle the plane effectively with the stick. They may be adjusted before the take-off so that the fore and aft balance of the plane may be as nearly perfect as possible, and they will then remain fixed. In most planes, they are adjustable in flight by a wheel or lever set in the cockpit.

The balance of the plane changes in various flights, due to shifts in the location or weight of the burden which it is carrying, such as passengers or fuel. "Nose-heaviness," the tendency of the plane to slip into a glide when pressure on the elevators is re-

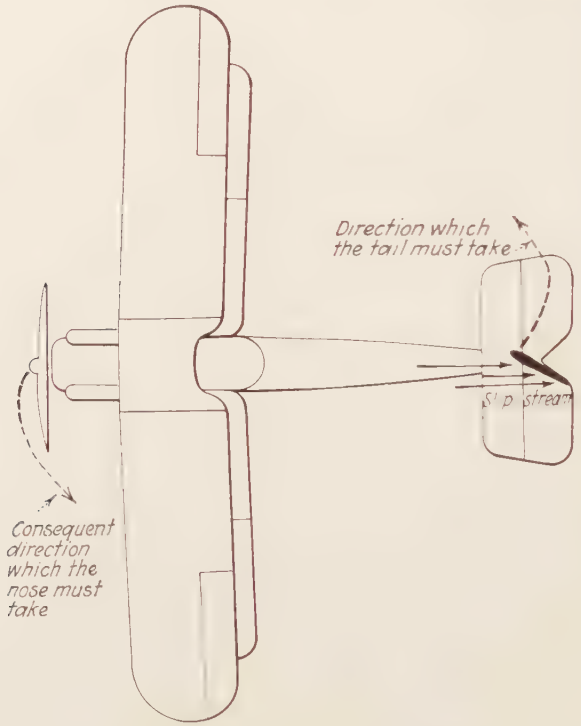


Fig. 70. Action of the Rudder

When the rudder is moved to the left the pressure of the slipstream against it tends to move the tail to the right, and thus to swing the nose to the left.

moved, or "tail-heaviness," its tendency to climb, would both be fatiguing to the pilot, if these could not be remedied by means of the stabilizer.

The Throttle. The throttle is a valve located between the carburetor and the engine. Its purpose is to regulate the amount of vaporized gasoline which enters the cylinders. The pilot oper-

ates it by means of a knobbed lever in the cockpit within easy reach of his left hand. (Sometimes planes are arranged so that the throttle lever is placed at the right hand, in order that a left-handed person may continue to yield the stick with his more skillful hand.) In ships where the pilot and student sit side by side, the throttle lever is located in the center of the cockpit. The throt-

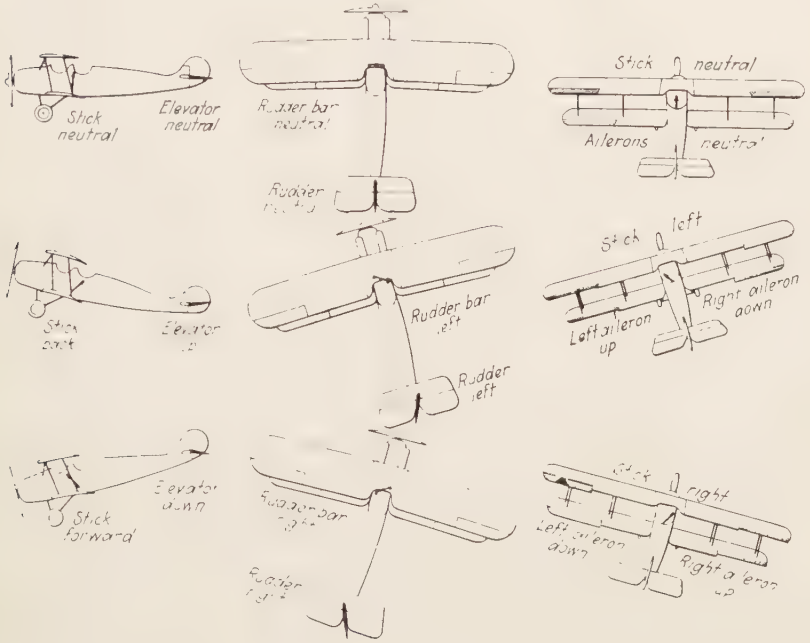


FIG. 71. HOW THE STICK AND RUDDER-BAR AFFECT THE CONTROL SURFACES

The arrangement of the stick and rudder-bar is such as to make their use as "instinctive" as is the foot brake of an automobile.

tle lever is pushed forward to open, and pulled back to close. In other words, it works in the same directions as the foot accelerator on an automobile. A shut-off valve in reach of the hand shuts off entirely the flow of gas to the carburetor.

There is often some question in the mind of the layman as to whether or not the airplane is equipped with a foot throttle. It is not. A foot throttle would be as unnecessary in an airplane

as in a motor boat, since, unlike the automobile accelerator, it is not in continuous employment throughout the flight. Moreover, the feet are already occupied with the rudder-bar and brakes.

Brakes. The purpose of the brakes is merely to hold the wheels fixed so that they will not roll. Therefore, the brakes are used only in taxying, or instead of blocks in warming up the motor. They have no functions as long as the plane is in the air. There are two brakes, one for each wheel. When the pilot wishes to make a sharp turn while the plane is on the ground, he may put on one brake, and use that wheel as a pivot.

The brakes are so arranged that they may be used by the feet at the same time as the rudder-bar. One brake is attached above each end of the rudder-bar. As the feet are normally in a position almost at right angles to the floor of the cockpit, and the rudder-bar is held by the feet near their balls, a forward and downward movement of the toe of one foot will press down on the corresponding brake. Some planes are equipped with hand instead of foot brakes. The Ford, for instance, has a universally mounted stick which is pushed to the right to brake the right wheel, to the left to brake the left wheel, and back to brake both wheels.

* * * * * * * * *

The student should make himself thoroughly familiar with the controls at the earliest possible moment. It is not sufficient to know that the movement of the stick this way or that will roll the ship or deflect the nose. He must know what happens to the control surfaces when he moves the stick or rudder. For example, he should *feel* his elevators going up slowly as he stalls for a landing. In other words he must think as a bird would think, about his flying.

SUGGESTIONS FOR READING ON CONTROL OPERATION

Chatfield and Taylor, *The Airplane and Its Engine,* chap. V. McGraw-Hill.

Jones, Byron Q., *Practical Flying,* chap. XVI. Ronald.

LePage, W. L., *A. B. C. of Flight,* chap. V. Wiley.

Clevenger, C. P., *Modern Flight,* chaps. I, II. Alexander.

Macmillan, Norman, *The Art of Flying,* chap. III. Mitchell.

Questions for Review

1. What are the primary controls? What are the secondary controls?
2. For what reason are the ailerons interconnected?
3. How do the elevators affect the movement of the ship?
4. Draw a diagram from memory showing how the stick is connected to the elevator and ailerons.
5. Do the same for the rudder-bar and rudder.
6. Explain the function of the fin and stabilizers. To what extent are their functions similar?
7. On what occasions would the pilot change the angle of the stabilizers?
8. What is the function of the throttle? How is it operated?
9. What are the advantages and disadvantages of fitting brakes to a light plane?
10. Why is an instinctive "feel" of the controls essential? How is it to be acquired?

CHAPTER VIII

AIRPLANE INSTRUMENTS

The development of instruments for use in flying has been slow and attended with great difficulties. Not even yet is it absolutely certain that a given instrument will perform satisfactorily under all conditions. Indeed, such perfection will probably be long in coming. The student, therefore, is taught not to place too much reliance on the instrument board. As a matter of fact, few training planes are completely and satisfactorily equipped with accurate and reliable instruments. But instruments are being built better than ever before. With the development of air transport lines, "blind flying," or flying by the use of instruments alone when neither earth nor sky is visible, is becoming more frequent. A cross-country flight and landing has been carried through "blindly" for purposes of experimentation. Several schools, furthermore, give special instruction in blind flying.

Instructors of the old school insist, however, that the beginner should learn to handle the plane by "feel," rather than depend too much on the instruments. They believe that the handling of the controls will become automatic much more quickly if this method is followed.

Instruments are of various kinds. Some have been developed for the measurement of flight performance. Others register the performance of the engine during flight. Still others are employed for navigation. The last are becoming more and more necessary with the increase of night flying and disregard for weather conditions. When a pilot has to fly through fog or clouds he is apt to lose his sense of balance and direction and must rely on his instruments. So it is obvious that neither "feel" alone nor instruments alone are sufficient.

The Instrument Board. The instrument board of a plane corresponds to the dashboard of an automobile. There are two

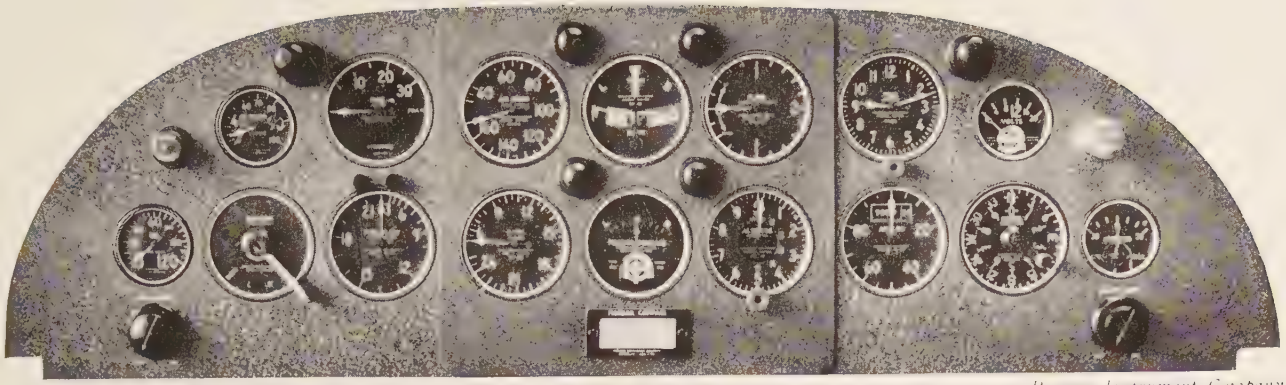


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FIG. 72. A COMPLETE INSTRUMENT BOARD

All the instruments which a pilot would ordinarily need are here. Each instrument has its purpose designated on its dial. Notice the arrangement of the instruments on the board.

requirements for the arrangement of the instruments on the board. The first is that all indicators and figures may be quickly and easily distinguished and their purpose readily apparent: more than one student has confused the altimeter with the tachometer. The second is that the instruments be so placed as to take up the minimum amount of space.

Instrument boards show certain tendencies toward standardization, it being considered good practice to group different classes of instruments together. The three main classes are: instruments recording the performance or condition of the power plant, those relating to stability or flight, and those for navigational purposes. Figure 72 shows an up-to-date instrument board.

Power Plant Instruments. In any weather and in all flights, power plant instruments are necessary to the pilot. They usually give warning of trouble in the engine before any indication of this trouble can be sensed by the pilot. Instant knowledge that some change in the functioning of the engine exists will ordinarily allow the pilot time to make a landing or to correct the trouble. The chief engine instruments are the tachometer, the thermometers, the oil pressure gauges, and the gasoline level gauge.

1. *The Tachometer.* The tachometer registers the number of revolutions made per minute by the engine crankshaft. Its purpose is to show at what speed the engine is running, thus enabling one to recognize instantly any involuntary reduction of speed and to prepare for trouble. The tachometer also shows to what speed one has throttled the engine after the take-off, or on long flights after one has determined what is the most economical cruising speed at which that particular engine will operate. In long flights, this instrument is of great importance. Any creeping-up of revolutions will be registered and can be corrected.

There are several varieties of tachometers. The chronometric type is used by the Air Service, and has proved reliable and accurate. It has a dial numbered to show revolutions of the engine during a given period. The pointer travels back and forth for each counting period. A vertical scale type has been perfected which takes up little room on the instrument board. When more than one engine is being used, the tachometers are mounted side

by side. The chief criticism of the chronometric tachometer is that it does not indicate change in speed gradually, but only the total change during a given period. Nevertheless, the readings are never more than one or two seconds late.

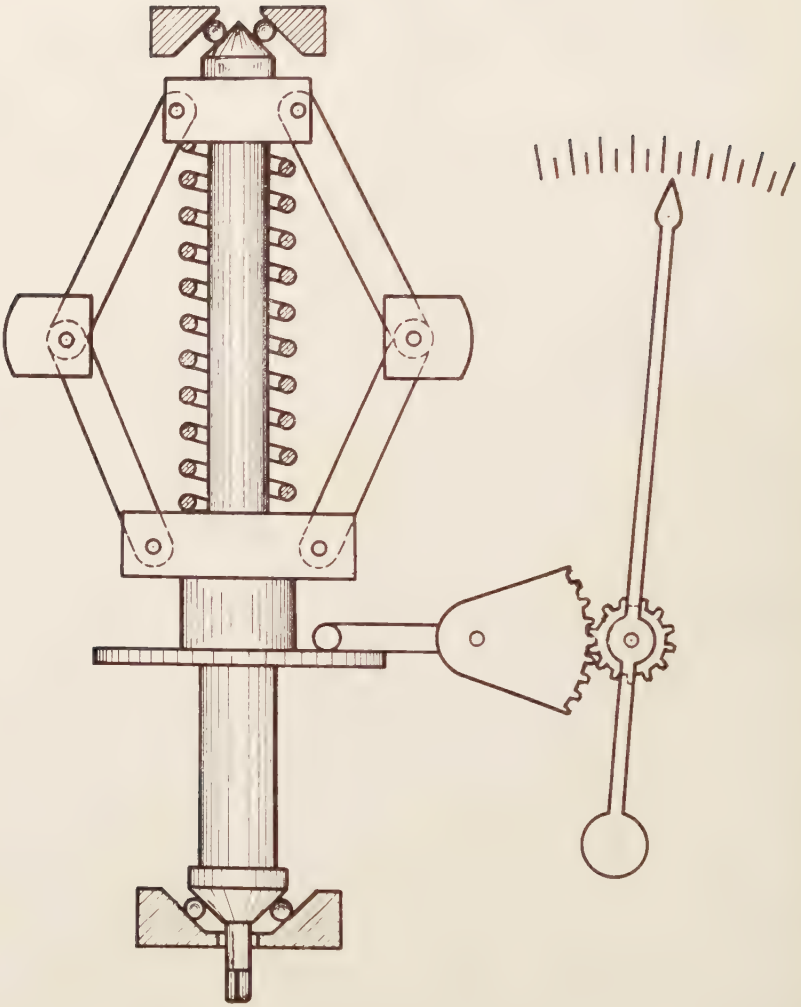
The centrifugal tachometer works on a simple principle. Weights are fixed about a shaft driven by the engine. These weights are made to work against a spring, and are connected to a pointer. As the speed of the shaft increases, centrifugal force throws the weights farther and farther away from the axis of rotation of the shaft. (See Figure 73.) Since it is known that the centrifugal force increases as the square of the rate of revolution it is possible to calibrate a dial to show the revolutions per minute of the engine.

Large airplanes sometimes use an electric tachometer, which takes advantage of the fact that the rate of revolution of the armature of a magneto determines the voltage. Connecting a magneto to the crankshaft and installing a properly graduated voltmeter on the instrument board will show the revolutions per minute of the engine shaft.

Other types of tachometers have been developed, but the chronometric, centrifugal, and electric have given best service. If more than one tachometer is used, pointers on dials should be parallel so that they may be quickly read, and so that the engines may be synchronized.

2. *Thermometers.* Thermometers are used to warn against overheating of the engine. In the case of a water-cooled motor, there are thermometers for the water and also for the oil. If the engine is air-cooled there is only one thermometer for the oil. The pilot watches his thermometer to see that the engine is operating efficiently. Particularly when the throttle has been cut for a long glide he must watch to see that the motor does not become too cold and choke when the throttle is reopened. The normal running temperature of an airplane motor is between 70 and 90 degrees centigrade. If it goes up to boiling, something must be wrong with the cooling system or with the engine itself or with the handling of it by the pilot.

Thermometers are of either the expansion or the electric type. In the first type a bulb is filled with gas or liquid, and connected



U. S. War Department

FIG. 73. OPERATION OF CENTRIFUGAL TACHOMETER

This instrument works somewhat like the familiar steam-engine governor. As the speed of the shaft increases, the spring is compressed, so that it is free and moves upward. This upward motion is transmitted to an indicator.

by a tube to a pressure gauge on the instrument board. (See Figure 74.) The bulb of a water thermometer is placed in the water system where it leaves the radiator or enters the engine water jacket, while the bulb of an oil thermometer must be in contact with the oil. With every change in the oil or water temperature the gas or liquid in the bulb of the thermometer expands or contracts, and this change in volume is registered on the graduated pressure gauge on the instrument board.

Electric thermometers are used for multi-motored planes. Resistance elements are placed in the water or oil which are connected to an ohmmeter and dial. Thermometers are usually

Pioneer Instrument Company

FIG. 74. A THERMOMETER

Here the bulb is shown, as explained in the text. It can be connected with the gauge on the instrument board, even though it is at a considerable distance from the engine.

located near the tachometer and pressure gauges on the instrument board.

3. *Pressure Gauges.* Pressure gauges are used to indicate the pressure of the gasoline (or air) in the fuel system and the pressure of the oil in the oil system. Sometimes a ship is equipped with a fuel flow gauge, which is merely a glass window set in the fuel tubing to show the gasoline. A similar instrument is sometimes used to indicate the rate of flow (or consumption) of fuel per hour. Pressure gauges are usually located near the other engine instruments. Any lowering of pressure below normal should be investigated immediately.

4. *Gasoline Level Gauge.* A gasoline level gauge measures the amount of fuel in the tank or tanks. It is an important instrument,

but it is not always reliable. It is not easy to build a gauge which will stand up under the vibration of the plane and the wash of gasoline in the tank as the plane tips from side to side. The earlier type employed a float resting on the surface of the gasoline in the tank, and connected by a silk cord to an indicator on the instrument board.

More recent design of gasoline level gauge is the so-called hydrostatic type. Its operation depends upon the principle that the pressure exerted by a volume of liquid is proportional to its depth. A "hydrostatic cell," forming part of the gauge system, is placed at the bottom of the tank. This cell is filled with air, and the weight of the liquid above it compresses this air. A small tube runs from the cell to a fitting on the outside of the tank, and from the fitting a connection tube goes to the gauge. These tubes transmit the air pressure to the gauge, which is a sensitive pressure indicator and is calibrated so that this air pressure is translated into gallons of fuel or other units of weight or volume.

This would complete the system were it not for the fact that because of the expansion of the air in the cell and tubing, due to changes in temperature and altitude, a certain small amount of air is occasionally lost. To assure the accuracy of the indicator, the balance of the system must be maintained by replacing the lost air. For this purpose a small pump is built into the gauge unit. Once a day, or whenever it is desired to know the fuel level with absolute accuracy, the knob of the pump is pulled out once and released. On the return stroke the pump automatically introduces the correct amount of air to balance the system and restore the accuracy of the indication. It is not necessary to operate the pump each time the gauge is read, as the indication is continuously correct, except for the slight errors due to temperature and altitude.

Stability or Flight Instruments. This class of instruments is not absolutely required except for flying at night or through fog. It is difficult for the pilot to maintain his balance except by the use of the instruments, when he is unable to see the ground or the horizon. Such instruments tell him whether he is climbing or descending, whether he is flying straight or turning, whether he is on a level course, etc.

1. *Altimeter.* The altimeter is usually a form of aneroid barometer which measures the atmospheric pressure. Since this pressure varies according to known laws as the altitude above sea level varies, the altimeter may be calibrated to show the vertical position of the plane at any given moment. The altimeter is so made that it may be set when taking off so that it will indicate the height of the plane above this taking-off place. When flying over uneven country, the pilot must remember that his altimeter is registering height above his taking-off place rather than above the place at which he is at a given moment.

Pioneer Instrument Company

FIG. 75. DIAL OF ALTIMETER

The altimeter shows height in thousands of feet above the zero point. By turning the knob at the bottom of the instrument, the reading may be set to read zero. The pilot has to reset this reading every day, or oftener, to conform to barometric pressure.

The ordinary altimeter has a box with flexible sides called an aneroid, which expands as the pressure of the air becomes less with increasing altitude. This expansion actuates through a system of levers (arranged to magnify the movement of the walls of the box) so that it moves the indicator of a pressure gauge on the instrument board. The dial uses a thousand feet of height as a unit. (See Figure 75.)

Since constant changes in atmosphere affect its reading, the altimeter uses an adjustable scale, hence the indicator should be set at zero at the start of each flight.

2. *Air Speed Indicators.* There is as yet no instrument which

will show directly how fast the plane is moving over the ground. The best substitute is an instrument which will show how fast the plane is traveling through the air. The usual method by which the pilot can tell his ground speed is to see how long it takes to pass from one known landmark to another. This, coupled with the air speed indicator, will tell him the velocity of the wind with approximate accuracy. In actual flight, the air speed will depend on altitude, the degree to which the throttle is opened, whether the plane is climbing or not, the amount of load carried, and so forth.

The air speed indicator can be used to see how near the stalling point the plane is, although a well-trained pilot will not need this visual indication, because his senses will already have informed him of the danger.

The usual apparatus of measuring air speed is comparatively simple. There is a pressure tube, and an indicator which records the pressure. This indicator is usually a diaphragm of sufficient delicacy to register slight pressures, yet strong enough to withstand any pressure to which it may be subjected by wind force. The indicator is connected to a pointer which shows miles per hour.

The usual form of air speed tube used in this country is the so-called Pitot-static. This is in reality a double tube. (See Figure 76.) The Pitot-static tube has to be corrected for altitude, about 2 per cent of the indicated reading being added for each thousand feet of altitude. For general use, the air speed indicator is sufficiently accurate as it is.

Great care is required in mounting the air speed indicator, although the best position varies with the make and type of the plane. Any effect from the propeller slipstream must be avoided.

3. *Bank Indicator.* The bank indicator measures the lateral stability of the plane. It shows whether the plane is banked properly. Various types are used, all of which take advantage of the resultant of the centrifugal force and gravity following a turn. Bubble, balls in glass tubes, liquids, and pendulums have all been used for inclinometers. At a proper angle of bank, centrifugal force holds the bubble, ball, or pendulum in neutral position, while any deviation is immediately apparent. Under ordinary conditions, the pilot can tell whether he has banked properly with-

out the use of the bank indicator, but for night flying it is essential.

4. *Turn Indicators.* Since the compass deviation is great during a turn, another instrument has been devised to register any turn of the plane from left to right, or vice versa, which again is exceptionally valuable in night flying. This instrument is gyroscopic in action. Figure 77 shows a bank indicator and a turn indicator combined.

5. *Climb Indicator.* Another instrument of increasing value is the climb indicator. It shows immediately any change in alti-

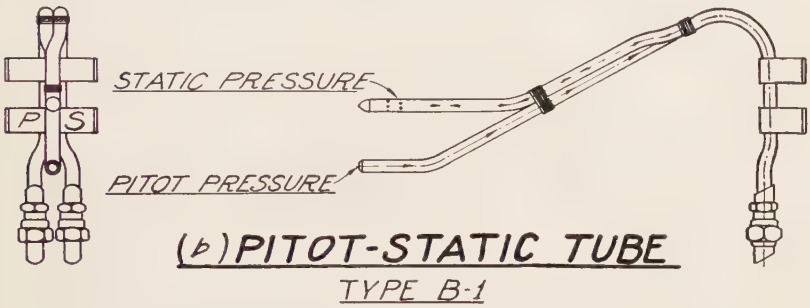


Fig. 76. Pitot-Static Tube

As the airplane passes through the air, pressure is built up in the pressure tube. The pressure increases, of course, with the speed of the plane. This pressure is conducted to one side of a thin diaphragm, to which a pointer is connected. The other tube (static tube) is connected to the opposite side of the diaphragm. Notice the small holes in the static tube, permitting the air to escape.

tude, and the rate of change in thousands of feet per minute. It is of great help in maintaining the desired altitude in cross-country flying, and is of outstanding value in mountainous country where wind currents are liable rapidly to change the altitude of a ship. Its indications do not depend upon the angle of climb, but upon the rate of change of altitude, enabling the pilot to climb as rapidly or to descend as slowly as possible without stalling.

6. *Drift Indicator.* This measures the angle of wind drift, which may be read directly. It shows the ground speed which is being made good, by noting the time it takes for an object on the ground to pass along the drift wire of the instrument.

Instruments for Navigational Purposes. These instruments are used for cross-country flights over strange territory, and for flying by night, through fog, over large bodies of water, etc.

Types of Compass. While no absolutely reliable compass has yet been perfected for plane navigational purposes, a skilled pilot with a carefully compensated compass can generally plot a course from point to point. All compasses, except gyroscopic ones, depend for operation upon terrestrial magnetism, that is, the north and south directions of the magnetic lines of force over

Pioneer Instrument Company

FIG. 77. COMBINATION BANK AND TURN INDICATOR

The lower instrument (glass curved tube) shows whether the plane has the correct angle of bank. The upper instrument shows whether it is turning. The turn indicator makes use of the principle of the gyroscope. It is not unlike a gyroscopic compass.

the surface of the earth. The compass must be placed where the pilot can see it easily, but in a position where local magnetism exercises the least effect. It is sometimes suspended behind the pilot, so as to be away from the motor, and is read by the use of a mirror.

Permanent magnetism in the steel parts of the airplane, and temporary magnetism in soft iron parts, due to the earth's magnetic field, cause deviation in the compass. For such errors, the compass can be corrected, or compensated, as it is called. Vibration of the engine, which also frequently causes trouble, can be reduced by careful installation. Airplane compasses have to be compensated frequently. There must be a correction chart for air-

plane compasses. This is simply a small card (shown in Figure 72), which shows additions or subtractions which must be made for deviation. Compass errors are treated at length in the chapter on Navigation.

Airplane compasses are of two main types: first, the ordinary magnetic compass, and second, the earth inductor compass. The first of these works like the mariner's compass, where a freely suspended magnet points along the magnetic lines of force. The magnetic needle is pivoted to a card on which are marked the points of the compass.

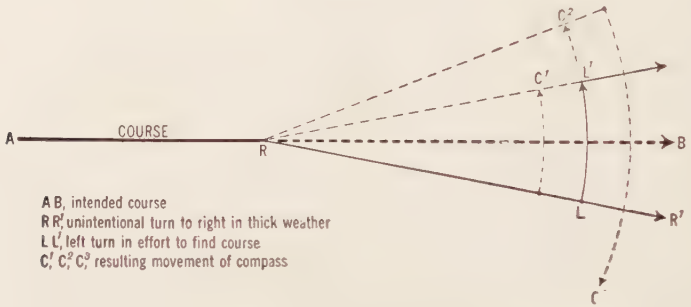
The Magnetic Compass. Contrary to common belief, the magnetic compass has but one serious fault: it does not indicate correctly on turns which require an appreciable banking of the airplane. A bank of approximately 20 degrees completely destroys its function, by bringing the compass card into contact with its case and "freezing" it, and thereby turning it with the plane. Then, when the plane comes level again, the card swings free and starts to oscillate.

If this occurs in thick weather, especially from an unintentional turn, the pilot usually interprets the swing of the compass, when it is freed, as a turning of his plane off the course. He immediately goes into a turn to get back on the course, and in doing so "freezes" his compass again and carries it farther out of position, in the direction of its swing. As he levels off out of this turn, the card is released again, and swings with even more momentum in the opposite direction. (See Figure 78.) Any further efforts on the part of the pilot to correct his course only cause the compass to swing more wildly, until finally it starts to spin slowly. By this time all sense of direction is lost and the pilot blames the compass. The only remedy for an oscillating compass is to maintain level flight until it comes to rest on its magnetic bearing, when it again becomes a useful instrument.

The magnetic compass may be considered as completely dependable when properly understood and when supplemented by a bank and turn indicator; as long as level flight is maintained, the direction of flight will be accurately indicated by the compass.

The Earth Inductor Compass. The earth inductor compass, which has received much publicity of late years, uses a different

principle to detect the terrestrial lines of force. A coil of copper wire is connected to a commutator. The position of the brushes which are riding on the commutator can be shifted. When these brushes are directed in a certain relation to the magnetic lines of force, no current will be shown on an indicator which is placed on the instrument board. By moving the brushes to a position at right angles to the above, a maximum deflection of the indicators will result. Between these two points are gradations which can be plotted.



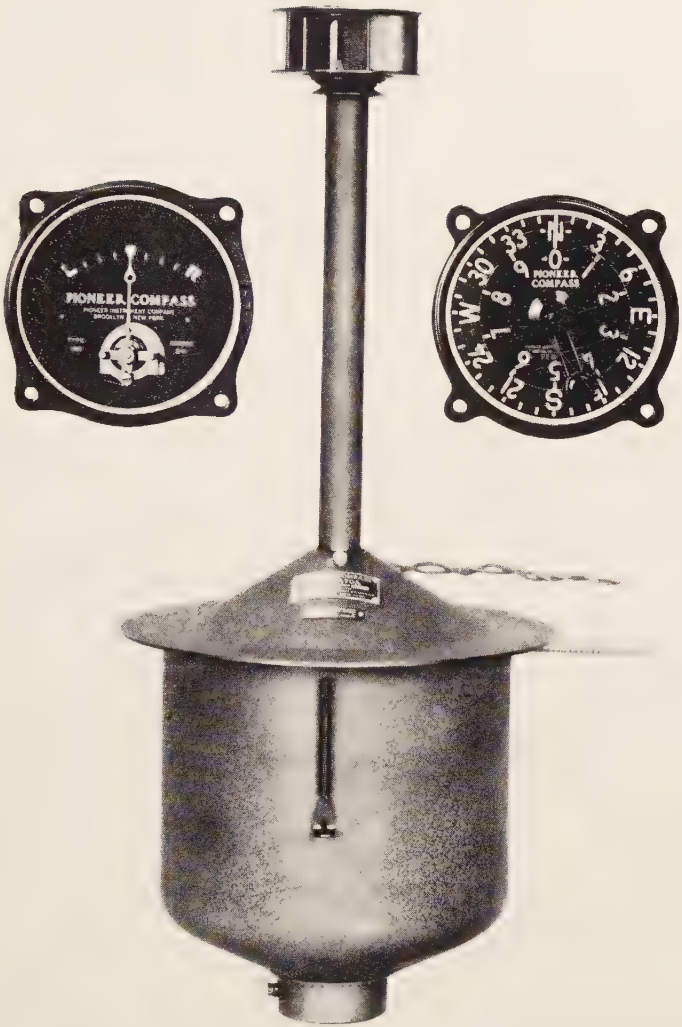
Rand McNally & Company

Fig. 78. Magnetic Compass Oscillation

The chief disadvantages of the mariner's compass is that it will not "stand still." Anyone who has tried to steer a yacht in a leeway knows this. The "freezing" of the compass against its case, enhances this trouble, as shown here.

The earth inductor compass consists of three parts: generator, controller, and indicator. The generator records the direction in which the plane is actually flying; the controller is set by the pilot for the direction in which he desires the plane to go; the indicator shows the amount of deflection from the intended course. Figure 79 shows the three parts of the compass.

The generator consists of a coil of copper wire. This is usually made to rotate by means of a small fan attached to the generator and set in the slipstream. The generator may be set in the rear end of the fuselage where magnetic disturbances are at a minimum. Suppose, for instance, that the plane is going directly west and also that the pilot desires to continue westward: the pilot turns the dial of the controller so that the pointer indicates west. By



Pioneer Instrument Company

FIG. 79. PARTS OF THE EARTH INDUCTOR COMPASS

From left to right: controller, generator, and indicator. The purpose and operation of the various parts are described in the text. The controller is set by the pilot for the direction in which he desires to fly. The generator records the direction in which the plane is actually flying. The indicator shows the amount of defection from the intended course.

thus rotating the dial, the brushes of the generator are so related to the magnetic lines of force that there will be no deflection of the indicator.

The indicator is made up of a semicircular dial, marked *zero* in the center, *left* on one side, and *right* on the other; and a pointer which is sensitive to electric current. If, when set as above, the plane heads due west, the pointer will remain at zero. If the plane turns slightly to the left the current picked up by the brushes and carried to the indicator will cause the pointer of the latter to turn to the left. If the plane turns still farther to the left, away from its intended course, the pointer will move still farther away from the zero point. The same process takes place when the controller is turned to indicate any other direction.

Miscellaneous Instruments. Instruments are constantly being developed and put into use which are intended to be improvements upon those already in the market. Numerous instruments have been invented for calculating the drift of the airplane from the wind velocity and air speed, and such devices, if reliable, would be useful. An excess of instruments on the instrument board is to be avoided, so that a reading of all dials may not detain the pilot's eyes too long from the horizon. Parenthetically, two very important instruments which should not be lost sight of are a watch and a map.

* * * * * * * * *

Although most instructors like their students to fly in the beginning without too much reference to instruments, there are others who claim that it is better to learn to fly by using instruments, and that the "feel" will come of itself.

The coming generation will probably possess a flying sense which they seem almost to be born with. They will fly without instruments as long as there is no special need problem, much as a harbor pilot does. But when instruments are needed they will use them, as does the ocean navigator.

SUGGESTIONS FOR READING ON INSTRUMENTS

Chatfield and Taylor, *The Airplane and Its Engine*, chap. XVII. McGraw-Hill.

Eaton, H. N., *Aircraft Instruments*. Ronald.

HUNT, F. L., *Aeronautical Instruments*. Government Printing Office.
COLVIN AND COLVIN, *The Aircraft Handbook*, chap. XIV. McGraw-Hill.

QUESTIONS FOR REVIEW

1. Obtain from a pilot his ideas as to how much a student should depend upon instruments.
2. Obtain his views as to the requirements of instruments in general.
3. Sit in the cockpit of a modern plane. Describe each instrument and its use.
4. Explain the operation of one type of tachometer.
5. Describe the thermometers used in an airplane with which you are familiar.
6. What are pressure gauges used for?
7. Interview an airplane mechanic as to the installation, operation, and adjustment of fuel gauges.
8. Why is the altimeter an important instrument? On what principle does it operate?
9. Name and describe the other flight or stability instruments.
10. Visit a repair shop, examine the parts of an earth inductor compass and write a report on its operation.

CHAPTER IX

ENGINES AND PROPELLERS

The student should know something of the types of engines used in various planes, of how these engines operate, and of how they should be cared for. Since the reliability of the plane depends in practically every case upon the performance of the power plant, he should be taught early in his training to observe the engine carefully, and detect signs of trouble as soon as they occur. In the previous chapter the various instruments registering engine performance have been described. This chapter deals with the power plant itself.

Engine Requirements. The fundamental requirement for any aircraft engine is that it be reliable under all conditions of flight. Any failure of the engine means an immediate landing, perhaps under most adverse conditions. For this reason, everything possible is done in the way of designing and testing airplane engines to increase the factor of reliability. A great deal has been accomplished in this direction. Engine failure, once of common occurrence, is today comparatively rare. The duplicate ignition systems found in airplane engines give an example of how sure the maker wants to be that reliability is secured. Furthermore, an engine with seven or nine cylinders can still keep the plane at flying speed if one or two fail to function. Not only is a moderately large number of cylinders desirable from the point of view of reliability, but they also tend to reduce vibration in the plane, which often causes trouble.

Engine manufacturers issue the most careful instructions as to the care of their engines, and ground schools drill students in the technique of servicing. Engine failure can usually be traced to poor care rather than to poor construction. Too much emphasis cannot be put upon careful inspection. (See Figure 80.)

After each flight the engine should be carefully inspected to

see that every part is functioning perfectly. At the end of a certain length of time, which varies with different engines (approxi-

Official Photograph, U. S. Navy

FIG. 80. ENGINE INSPECTION IS IMPORTANT

In the Navy, where absolute reliability is called for, engine inspection is rigorous. Here is the aircraft squadron, lined up with engines ready for examination. Service in the air depends upon the vigilance of the ground crew.

mately 300 hours of flying), the engine should be given a complete overhaul.

Because much of the commercial value of the plane and its

cost of operation depend upon its lightness, every endeavor, consistent with reliability, is made to reduce the weight of the engine. The materials used are largely aluminum and steel alloys. This increases the expense, in comparison with automobile engines, but makes for lightness.

Another requirement is what the automobile owner calls "pick-up." The pilot wants the engine to respond immediately to the throttle. His engine must idle when he glides and lands; it must deliver full power when he takes off, or in an emergency.

Engine Types. Many types of engines have been tried in airplanes. To avoid vibration, it is not customary to have less than four cylinders (although three are sometimes used); nor is it usual to place more than nine cylinders in one engine. The chief types of engine in use now are:

1. The radial engine with stationary cylinders arranged around a crankshaft. The Wright Whirlwind engine belongs to this type. The air-cooled radial type, because of its efficient operation, its lightness and compactness, and the fact that it can be overhauled without removal from the plane, has become highly popular.

2. The vertical engine, or "in-line" type, which, like the automobile, has its cylinders in a row directly above the crankshaft, is also used, both for air-cooled and water-cooled models. Sometimes this type of engine is built to be run in inverted position.

3. The Vee-engine, such as the Cadillac motor car has used for so many years, is also used in airplanes.

4. The W-engine, which has three instead of two rows of cylinders. (See Figure 81.)

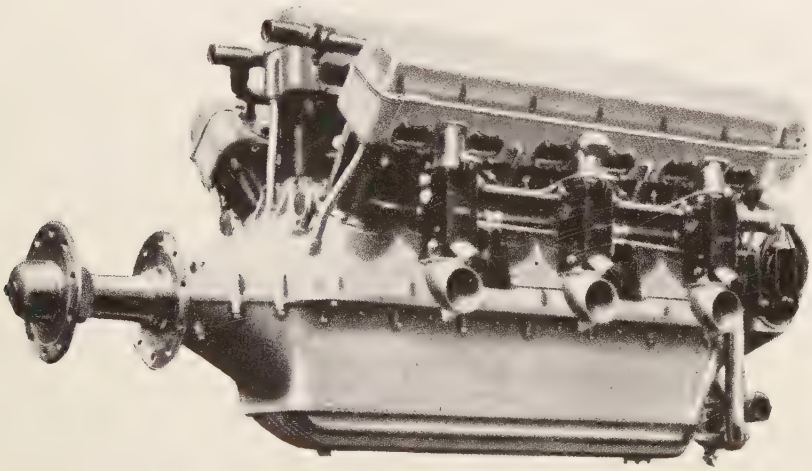
5. The X-engine has four rows of cylinders, two on each side of the crankcase, so that it looks from the front like the letter X.

6. Horizontal-opposed engine. Sometimes an engine is built so that the cylinders are in horizontal rows directly opposite to each other on either side of the crankcase. This makes a flat engine.

Perhaps there is no one type of engine better than the rest. Engines are still in a state of development, from which no ultimate design has emerged. On the one hand, there is great activity

in developing engines for small sport planes; and, on the other hand, those intended for the great commercial planes. For the small engine, in addition to reliability, the manufacturer wants lightness and power, and above all, he wants to make his engines on a production basis, so as to keep his costs low.

Radial Engines. Radial engines, particularly of the air-cooled variety, have had a great vogue, particularly in the United



Isotta-Fraschini

FIG. 81. W-TYPE OF A WATER-COOLED ENGINE

This engine is in reality three 6-cylinder engines operating on a single crankshaft. The complication of parts has prevented this type of engine from being popular, at least in this country. There are 18 connecting rods, 72 valves, and 6 carburetors. Starting is by compressed air.

States. They are not, as is commonly supposed, the outgrowth of the old rotary type of engine, in which the cylinders revolved with the propeller, the crankshaft remaining stationary, but were developed at about the same time. Many record flights have been made in this country with radial engines, including those of Lindbergh, Chamberlin, and Byrd.

In the radial engine, stationary cylinders are arranged around a crankcase. (See Figure 82.) There are usually three, five, seven, or nine cylinders.

Pratt & Whitney

FIG. 82. RADIAL AIR-COOLED ENGINE

This is a good example of American engine design. This engine develops 500 H. P. at 1900 revolutions per min. Its weight is 855 lbs. Notice the reduction gear, which is so arranged that for every two revolutions of the engine the propeller revolves but once. Notice also, that a three-bladed propeller is provided for.

Construction is such as to give the greatest efficiency per pound of weight. Radial engines are normally of the four-cycle type, although the two-cycle arrangement has the advantage of great simplicity, as may be judged from Figure 83.

The nose of a radial engine should be carefully cowled. Shutters are usually supplied, which may be controlled from the pilot's seat. (See Figure 84.) The mounting of a radial engine is shown in Figure 85.

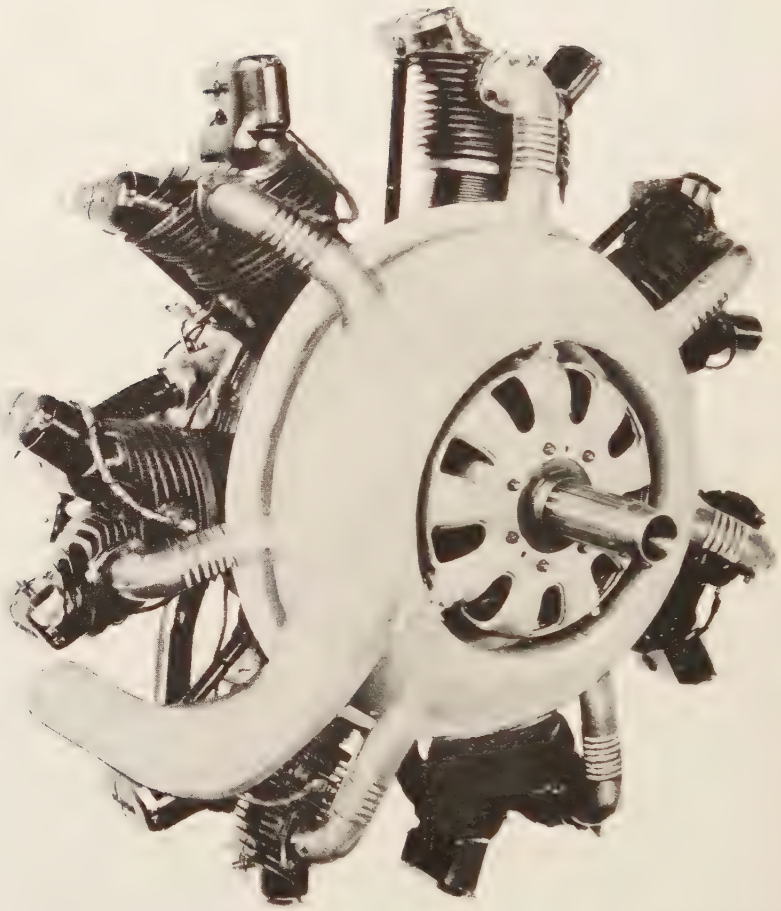
Aircraft Holding Corp.

FIG. 83. TWO-CYCLE RADIAL ENGINE

This shows all the important parts of this two-cycle air-cooled engine. There are no valves, the exhaust and intake being taken care of by means of ports in the cylinder walls. Notice the connecting rod assembly.

Non-Radial Engines. The radial type of engine offers much head resistance. Hence, there is a constant effort to find some equally efficient and serviceable form of engine which can be streamlined more effectively. The four-in-line engine is preferred by many owners of private planes, perhaps because of its similarity to the automobile engine.

Non-radial engines may be water-cooled or air-cooled. The former are the more common. The water-cooled in-line type of engine is in reality merely a refinement of the automobile engine, and looks very like one. (See Figure 86.)

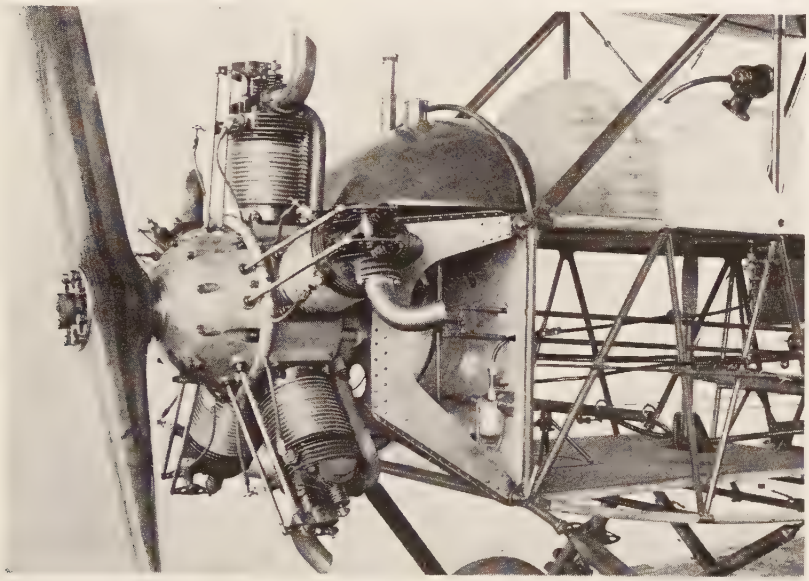


Wright-Whirlwind

FIG. 84. RADIAL ENGINE SHOWING COWLING

The cowling is so arranged as to give adequate cooling without presenting too much resistance to the air. Notice the exhaust collector, also the shutters.

Air-cooled non-radial engines have found a good deal of favor, in the smaller sizes. One American company offers such a motor, developing 90 horsepower at 1900 r.p.m. It has two magnetos, a duplicate ignition system, and is noticeable for lack of radiator, water jacket, pump, or piping. The engine is turned over by a hand starting gear, and by virtue of a special magneto



Flugzeugbau Hopfner, Vienna

FIG. 85. ENGINE MOUNTING

This shows how the engine is attached to the fuselage. An advantage of the radial engine is that it can be overhauled without being taken out of the plane. Notice the rudder-bar and stick.

arrangement there is high spark plug efficiency at low number of revolutions. Like the automobile engine, the oil is carried in a sump at the bottom of the crankcase, which supplies enough lubricating fluid for 15 hours in the air and does away with the external oil tank.

Another engine, similar in its general appearance, but small in capacity, is shown in Figure 87.

Cooling Systems. Overheating has always been a great

problem in the design and operation of airplane engines. Until recently, and particularly during the war, the water-cooled engine,

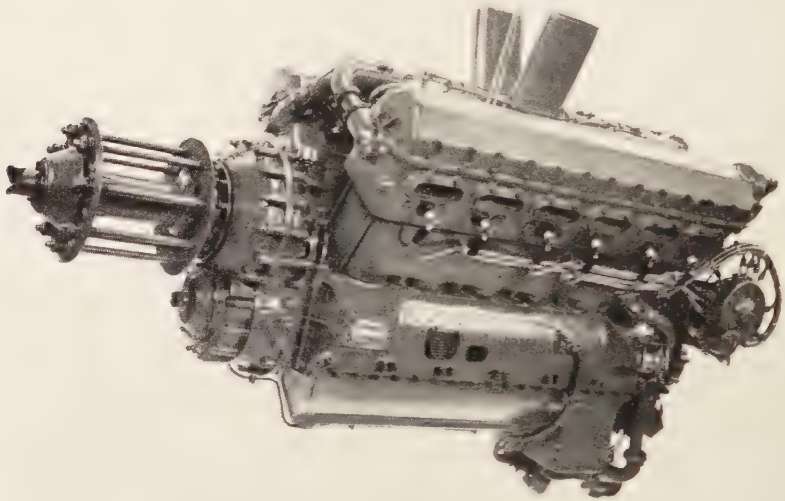
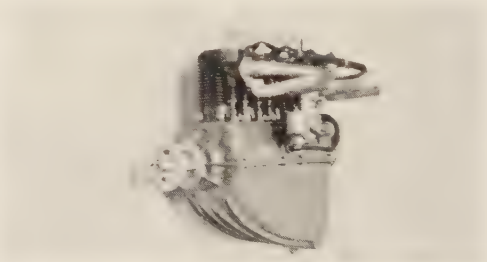


FIG. 86. WATER-COOLED V-TYPE ENGINE

This is really just a development of the water-cooled automobile engine, with certain additions, and refinements, such for example as the reducing gear (shown at the left). This engine, built by Rolls-Royce, is very popular in England.



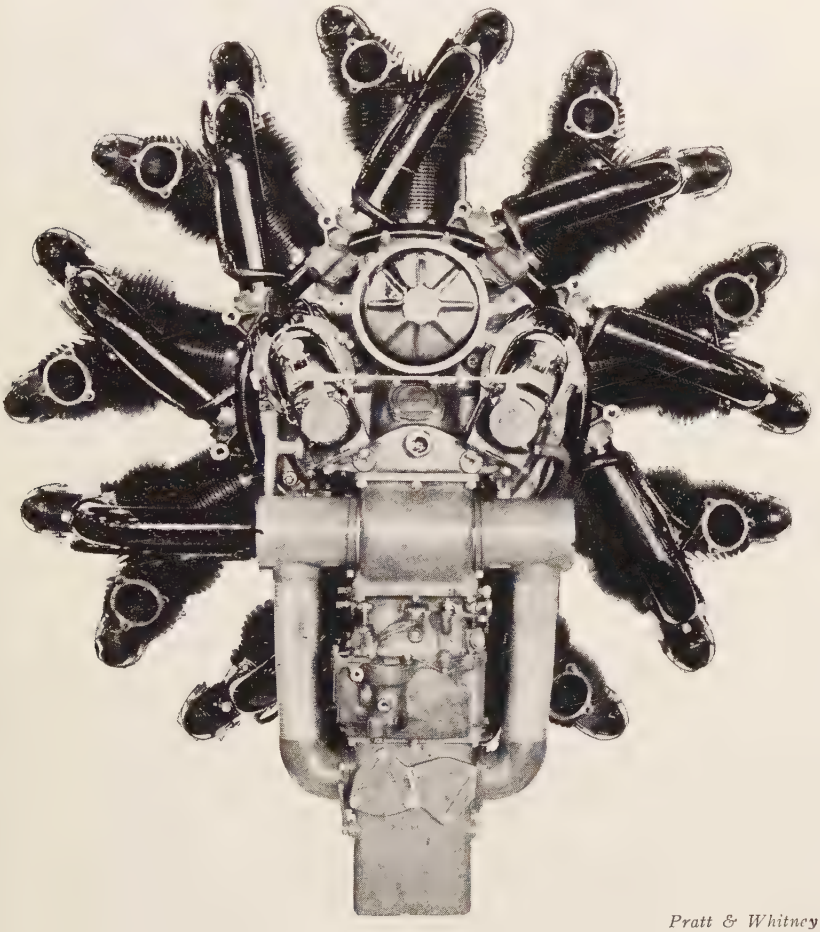
Heath—Henderson

FIG. 87. MOTORCYCLE TYPE OF ENGINE

This is a very small four-cylinder air-cooled engine, very like those used in motorcycles.

with its uniform temperature, was dominant. The air-cooled engine, however, has been making rapid strides. The weight of the

water-cooled type of engine, with its water jackets, its pump, and its circulating system, is considerably more than that of the air-cooled variety.



Pratt & Whitney

FIG. 88. ENGINE ACCESSORIES

The rear view of an air-cooled radial engine. (Series C Wasp.) The intake manifolds, the magnetos, and the carburetor are shown.

Cooling by air has proved a problem not easy to solve. In the radial engine, cylinders are separated from each other so as

to permit ample circulation of cool air to all parts of them. To obtain this adequate cooling, radial engines must be built in such a way that they offer considerable resistance, and retard the speed of the plane. But systems of cowling have been developed which have reduced this to a marked extent. It is desirable to streamline the power plant as much as possible, but it is even more important to keep the temperature of the engine at a proper point. To do this in warm weather requires a large volume of air. The fins observable over the surface of an air-cooled cylinder are to give greater area for cooling purposes.

In both the air- and water-cooled engines there are adjustable shutters to regulate the flow of air. These may be operated from the cockpit. In the case of the air-cooled engine adjustments are perhaps even more necessary. The shutters are closed, for example, when starting the engine, are kept shut until it warms up, and opened for the take-off. In the radial air-cooled engine, the cylinders are located in the slipstream and project from the cowling, so that they are sure to obtain enough air. The vertical air-cooled engines have ducts on the side which admit air to the cylinders.

Radiators for water-cooled engines are usually like automobile radiators in appearance. Some have cooling surfaces made up of small tubes; others have cooling surfaces made up of flat plates.

Recently, certain liquids have been developed to take the place of water in water-cooled power plants. These chemicals have so many advantages over water as a cooling medium that they may have a considerable effect upon the future design of engines.

Cylinders. Great care is taken to design cylinders so that they will withstand heat and at the same time permit of proper cooling. Exhaust valves are sometimes at red heat when the throttle is wide open. It is this operating at high temperature which makes it so imperative to inspect the engine frequently. The ordinary air-cooled cylinder is a steel forging, while the ordinary water-jacketed cylinder is of cast iron. Pistons are usually of aluminum alloy. Sometimes in water-cooled engines steel walls are used, and a sheet steel water jacket is welded around it. Some radial engines have steel barrels with aluminum alloy heads

shrunk over them. Exhaust valves are normally facing the front, to take advantage of the slipstream, with intake valves on the back. This arrangement makes for fuel economy.

Carburetion. The carburetor governs the mixture of fuel and air to the cylinders. It is not the usual practice to heat the manifold as in automobile engines to secure uniform vaporization, but some engines have hot spots mounted above the carburetor which serve to vaporize the fuel and make the engine smooth running. Usually this hot-spot temperature may be regulated by the pilot from his seat.

Ignition. Sparks are furnished either by magnetos or by a storage battery kept at full charge by a generator. The airplane which does not carry lights or electrical apparatus can run on the magneto with perfect satisfaction (see Figure 88), but batteries are necessary for larger planes carrying lights and radio. Normally there is a magneto system installed, any way, in addition to the battery system.

Starting the Engine. Airplane engines of the smaller sizes are still started by spinning the propeller by hand. In many cases, however, there is some form of starting device included in the equipment of the plane, operated by hand, electricity, or, rarely, by compressed air.

The hand starter is often employed, being light and simple, consisting merely of a hand crank geared to the rear of the crankshaft. But not many designs lend themselves to this arrangement. An improvement on this is the inertia starter, in which a flywheel is made to spin by means of a hand crank, and when it reaches a high speed is thrown in gear with the engine crankshaft. This turns the crankshaft rapidly for a few seconds, which is usually enough to start the engine.

Electric starters require a storage battery, which adds to the weight. Compressed air starters operate from a tank. If the engine does not start almost immediately, they must be pumped up again. Another type of starter pumps gasoline vapor into the cylinders which are then fired by a hand magneto.

The student should learn at once how to take care of the engine in his plane. Much depends on how he starts it. The spark control, if there is one, should be retarded one-third. The mixture

control should be turned to "rich." The throttle is opened only slightly, just barely "cracked." The pressure in the gasoline system is pumped up. In the case of an air-cooled engine, the nose shutters are closed. If the weather is cold it may be desirable to prime the engine so that it will start more easily.

If a starter is used, everything must be done beforehand to make certain that the engine will "take" at once. The ignition switch is turned to "on." If a hand starter is used, it should be wound up hard enough to give two or three full revolutions. When the engine starts it should be run slowly at first, before the plane is allowed to start. While warming up, the engine should not be given the full throttle for more than a few seconds, just enough time to see that everything is operating satisfactorily.

Careful watch should be kept of the oil pressure gauge to see that the lubrication system is working properly. Engine trouble may often be anticipated before the start, and careful attention to details will add to the safety of the pilot and the length of the life of the engine.

Fuel. Only the best gasoline should be used in the airplane motor. Economy in this respect is unwise, since the fuel price is but a small item in the operation of the plane, and the damage to the motor through poor fuel may be considerable. "Anti-knock" qualities are most important, and if the performance of the gasoline in this respect is not known, from 15 to 20 per cent benzol may be mixed with the gasoline. Ethylized gasoline may also be used advantageously. Sometimes it may be necessary to fill the tank with ordinary automobile gasoline, but in such cases the engine should not be operated at or near full throttle, because low-grade gasoline is apt to cause overheating, with resultant damage to the engine.

In filling the tank, the gasoline should be carefully filtered. A chamois cloth is useful, as this will eliminate water or dirt.

The fuel tank is made of some light substance such as aluminum, duralumin, or some form of steel plate. These tanks are usually divided into smaller compartments by baffle plates with large enough openings in them to permit free passage of the fuel, but serving to keep the fuel from washing back and forth.

The piping which carries the gasoline may be made of copper

or duralumin. Since vibration of the engine may cause a break in the feed line, joints are made with the greatest care, either of brass or rubber. Although the rubber joint ultimately is softened by the gasoline, it rarely fails suddenly. Gravity feed is not always possible or desirable in airplanes. (See Figure 89.) Hence, pumps must be used to keep the pressure up to the required 2 to

Sport & General Press Agency, London

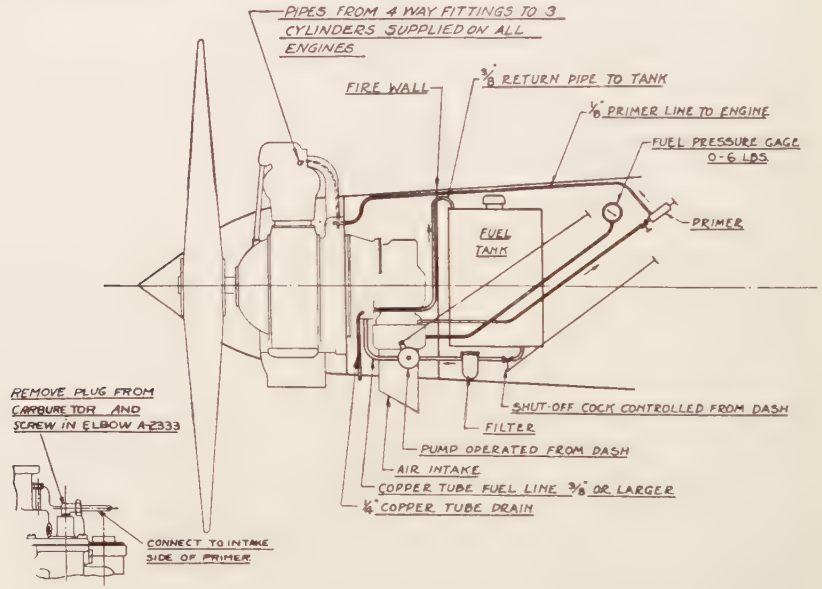
FIG. 89. THIS IS WHEN THE FUEL SYSTEM MUST WORK

Modern airplanes have fuel systems so designed that they will function properly under any and all conditions. This is an English "Moth," flying in a position when "gravity feed" operates under difficulties.

4 pounds. (See Figure 90.) These are driven by the engine or by a windmill in the slipstream. Sometimes there is an emergency tank in case the regular supply system fails, and often a special hand-driven pumping system to substitute for the regular one, should it fail. In case the fuel line should break, and fire ensue, there is always a shut-off valve where the pilot may reach it easily.

Engines are designed to consume as little fuel as possible,

not only because its weight is considerable, but also because the aim is to reduce the cost of operation. Fuel consumption is usually measured by the power developed, or pounds of fuel per horsepower per hour. Fuel consumption increases with altitude, because the general efficiency of an airplane decreases as the density of the air decreases. This is overcome in some engines by


PIPES FROM 4 WAY FITTINGS TO 3 CYLINDERS SUPPLIED ON ALL ENGINES
FIRE WALL
3/8 RETURN PIPE TO TANK
1/8 PRIMER LINE TO ENGINE
FUEL PRESSURE GAGE 0-6 LBS
PRIMER
FUEL TANK
REMOVE PLUG FROM CARBURETOR AND SCREW IN ELBOW A-2333
SHUT-OFF COCK CONTROLLED FROM DASH
FILTER
PUMP OPERATED FROM DASH
AIR INTAKE
COPPER TUBE FUEL LINE 3/8 OR LARGER
1/4 COPPER TUBE DRAIN
CONNECT TO INTAKE SIDE OF PRIMER

Pratt & Whitney

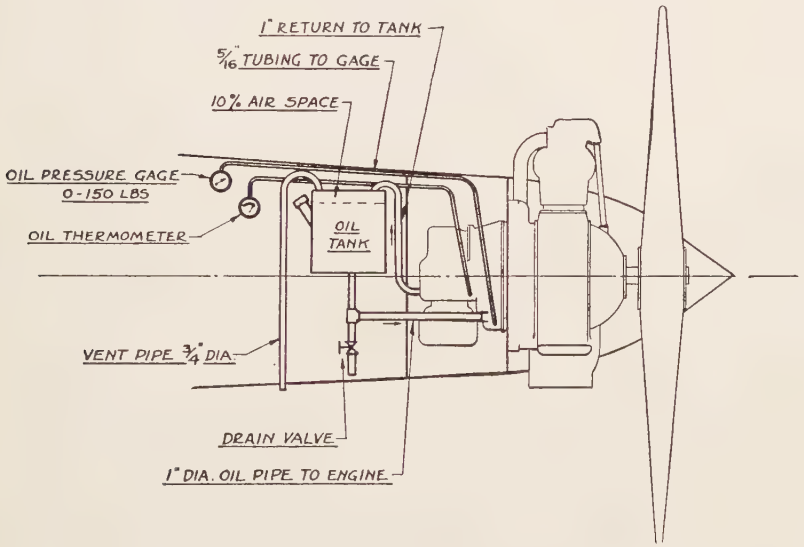
FIG. 90. DIAGRAM OF FUEL SYSTEM

The fuel tank and its connections to the engine, together with the means of priming, filtering, pumping, and recording the amount of the fuel, are extremely important, since any failure may disable the power plant.

the use of a supercharger which compresses the air, on its way to the motor.

Lubrication. Lubricating oil should be of the best quality obtainable. Careful standards have been developed for oils which give best performance. Poor oil gives low pressure, high oil temperature, and excessive consumption. Dirt must always be kept out of the oil. To be sure none has got in, oil should be changed every 15 or 20 flying hours.

The airplane engine, like the automobile, is lubricated by oil under pressure. This pressure is furnished by a pump geared to the crankshaft. Some engines keep their oil supply in sumps at the bottom of the crankcase, but many of them have to have an extra tank from which oil is drawn, conducted through a system of pipes, forced through the bearings, and returned to the tank again by scavenging pumps in the crankcase. (See Figure 91.)



Pratt & Whitney

FIG. 91. LUBRICATION SYSTEM OF AN AIR-COOLED MOTOR

This shows the external system only, with an oil tank. Some engines use the engine crankcase instead of an external tank.

As soon as the engine is started, the oil pressure should register, and if no pressure is shown after a few seconds the engine should be immediately stopped. Any small leak in the oil line will let in air and prevent the pump operating rapidly. At least 25 pounds pressure should be registered when the motor is idling, and this will increase with the speed of the motor.

Propellers. The propeller, or "prop," shares an equal responsibility with the engine for the reliability of the plane. For many years propellers were made of wood, but recently the trend

has been strongly in favor of metal propellers, and particularly those of aluminum alloys, such as duralumin. Figure 92 shows one of these aluminum alloy propellers attached to an engine of the radial type. Wooden propellers are usually of birch, built up strip by strip, of carefully dried material, and often covered for part of their length with brass sheathing to protect from abrasion. While wooden propellers are cheaper than metal ones, their efficiency is perhaps less, and their life is shorter. Furthermore, repair of metal propellers is usually a simple matter, while injury to a wooden propeller normally means replacing it.

In addition to strength, a propeller must have balance. When mounted on frictionless bearings it should show no tendency to

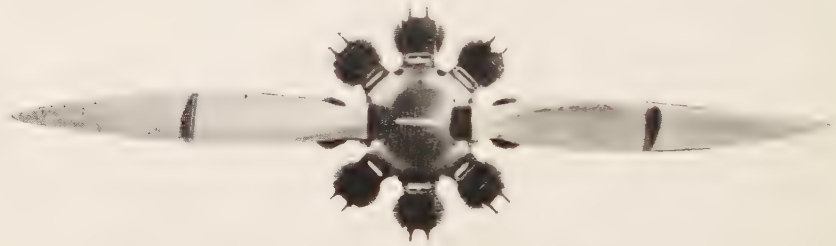


FIG. 92. AN ALUMINUM PROPELLER

This propeller is forged from a billet of aluminum, much as steel is forged, and is then so accurately machined that even when placed on frictionless bearings, it will not turn of its own weight. Perfect balance is essential in a propeller.

turn, in any position. After having been in operation some time, the surface of the propeller becomes rough or pitted and tends to get out of balance. This is particularly noticeable in seaplanes, where the salt spray has a corrosive effect. Care is taken to keep the surface in good condition.

The propeller must be adapted to the engine which drives it. It is usually set so that the engine will be held to its rated speed at full throttle when it is in level flight at low altitudes. The carburetor and the ignition of the engine are also set and adjusted with this in mind. Engineers work out carefully the maximum efficiency of the propeller, that is, the ratio between forward speed and speed of rotation which best fits the propeller, the engine, and the characteristics of the plane.

A high-speed engine requires a propeller of small diameter if it is to run at full engine speed. To offset this, reduction gears are sometimes used. These gears permit a larger propeller, since it rotates at a speed slower than that of the engine.

In designing propellers, the endeavor is to obtain a large thrust in proportion to the energy required to turn the blade. A small propeller is not efficient because the slipstream is then too rapid and, as explained in the chapter on Aerodynamics, a large slipstream is much more efficient.

* * * * * * * * *

If there is any one thing which differentiates the experienced pilot from the inexperienced one it is his attitude towards his engine. He thinks more of its physical condition than he does of his own. When the novice has had an engine fail once he will understand why this is so.

SUGGESTIONS FOR READING ON ENGINES AND PROPELLERS

Chatfield and Taylor, *The Airplane and Its Engine,* chaps. VI, VII, VIII, IX. McGraw-Hill.

Jones, Byron Q., *Practical Flying,* chap. XVII. Ronald.

LePage, W. L., *A. B. C. of Flight,* chap. VI. Wiley.

Champion, C. C., *Recent Developments in Aircraft Power-Plants.* Society of Automotive Engineers.

Colvin and Colvin, *Aircraft Handbook,* chaps. IV to XIII. McGraw-Hill.

Pagé, Victor W., *Modern Aviation Engines,* chap. I. Henley.

Questions for Review

1. Interview three pilots on the subject of engines and the importance of caring for them.

2. How do the requirements of an airplane engine differ from those of an automobile engine? From a motor boat engine?

3. Obtain from a qualified mechanic an outline of the procedure followed in overhauling an engine.

4. Enumerate the main types of airplane engines, and mention their leading characteristics.

5. Obtain from a qualified mechanic or engineer a statement of the relative advantages of two-cycle and four-cycle types.

6. Clip from the trade press descriptions of two recent engine developments. What advantages and disadvantages do they appear to have?

7. What is the usual procedure in starting the engine of a light plane?

8. How does a carburetor work?

9. What are the things which the pilot should bear in mind regarding the lubricating system?

10. What are the chief requirements of a propeller?

PART THREE

ELEMENTARY MANEUVERS

Chapter X. Straight Flying

Chapter XI. Turns

Chapter XII. Taxying

Chapter XIII. Take-Offs and Climbs

Chapter XIV. Approaches and Landings

The elementary maneuvers of an airplane are easy to understand, but not so easy to execute. Nothing except actual hours in the air will give the student the slightest skill in them. Yet this time (and very expensive time it is) can be materially shortened if the student, through a painstaking study of these chapters, with their text, photographs, and diagrams, will take the trouble so to familiarize himself with the various evolutions that he will know in advance exactly what the instructor is going to expect of him.

The first subject treated is that of straight flying. This is not an easy thing to do, especially if any wind is blowing. The next chapter tells how turns are made, and how the controls must be managed to complete them successfully. Chapter XII explains the operation of the airplane while moving on the ground, that is, taxying. Next follows a treatment of taking off the ground and climbing into the air. The section ends with approaches and landings, landings requiring the most skill of all elementary maneuvers, if not of all maneuvers.

Fig. 93. A Plane in Straight Flight

Lockheed Aircraft Company

Straight flying is generally taught first. The student picks out a point on the horizon to fly toward in maintaining a straight and level course.

CHAPTER X

STRAIGHT FLYING

When, from your initial flights, you have acquired a knowledge of the use of the controls, you are given a good deal of practice in straight flying. (See Figure 93.) That is, straight flying is normally placed at the beginning of the flight training process. Some instructors, however, prefer to teach turns ahead of straight flying, maintaining that the principles used in turning the plane must be employed in keeping the plane on its course. Straight flying means the maintenance of the ship on the same compass course, turning neither to right nor left, and at the same time maintaining a uniform height above sea level. In other words, it means keeping the ship traveling in a straight line. The instructor makes the take-offs and landings during these elementary lessons.

It would appear from watching an airplane in flight that maintaining a straight course was a simple problem. Straight flying is, however, more difficult than you might expect, due to the inherent instability of the plane, to its tendency to veer always to the left, and to air disturbances.

Altitude for First Flights. After the initial climb, the instructor-pilot levels off at a height from the ground depending somewhat on the wind, the amount of air traffic, and the contour of the terrain. If there is sufficient landing space, and no other planes in the vicinity, a good height is five hundred feet. At that altitude, you are high enough to fly with safety, but low enough so that your progress over the ground is apparent. (At a great height, your movement would be scarcely perceptible.)

Flying a Straight Course. When the pilot hands over the controls to you, he expects you to maintain a straight and level course. To keep a straight course, sight a point on the horizon in reference to some part of the plane. Any yawing (swerving

from side to side) can then be detected. If you fly far enough so that you overtake the object originally chosen, you must choose some other object, in the same direction, to sight by. No exact point on the plane can be taken as a sight. It will depend upon several factors, such as the height of the student's eyes above the fuselage. You must determine this point for yourself. The principle is the same as in the lining up of the sights of a gun in order to hit a target. It is apparent that you must always use the same points in the plane for sighting purposes.

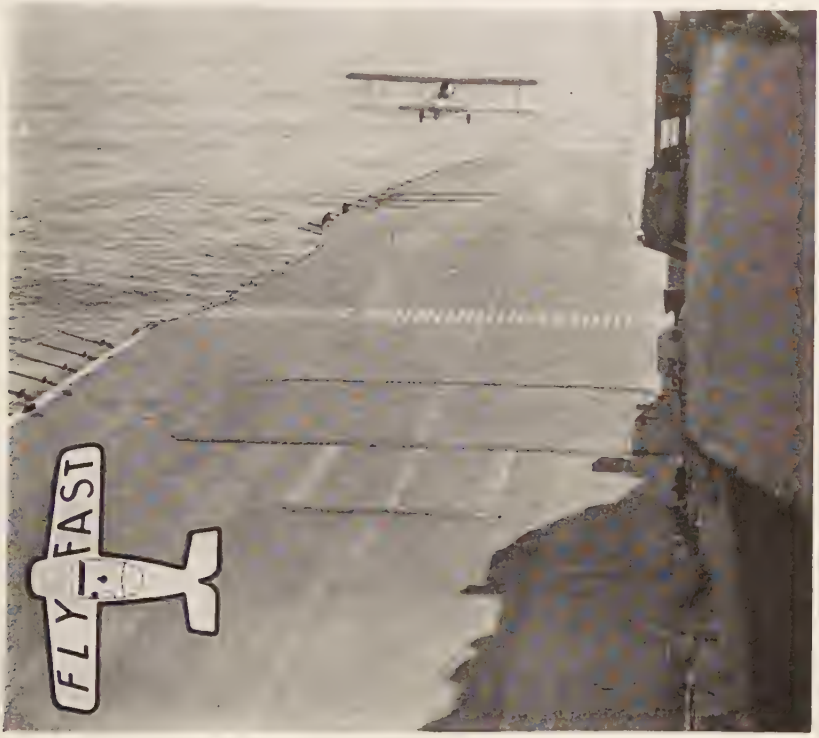
Once you have set a straight course, you will find some difficulty in maintaining lateral balance. As soon as you are able it is better to determine lateral balance by the fuselage rather than by the wings, so that your entire attention may be focused on the nose. Before you know exactly what position the nose will take when the wings are level, however, it is necessary to give an occasional glance at the wings to see that they are both in the same relative position in regard to the horizon. (See Figure 94.) If one of the wings has a tendency to drop, its aileron should be lowered and the opposite rudder applied. Learn from the start to apply aileron and rudder proportionately.

The fuselage creates a blind spot directly in front of you. In order to ascertain that there are no obstacles ahead, which are thus hidden, the nose should be frequently dropped or swerved for a moment, so that you may look ahead. Since you have not yet had practice in turns, however, the instructor will probably make it his duty to watch this blind area during the first hours of instruction.

Unless you attempt to maintain your course by means of landmarks, the plane will tend eventually to make a wide circle to the left. This tendency of the plane to turn to the left is due to two things: the "slipstream" and the "torque." The slipstream (the swirl of air thrown back by the propeller) does not move backwards from the nose in two symmetrical halves. On the contrary, the propeller spins clockwise, when viewed from the cockpit, and the pressure of the slipstream against the side of the fuselage, and against the fin and rudder, is sufficient to deflect the ship slightly from its course and to the left.

The clockwise spinning of the propeller tends to throw the

plane slightly in an anti-clockwise direction, on the principle that action and reaction are opposite and equal. The torque tends to make the propeller bank the plane as if for a left turn. Just as a lever has to take its force from pressure on some other object, so



Official Photograph, U. S. Navy

FIG. 94. KEEP YOUR WINGS LEVEL!

This is very important, especially when you are taking off. Glance first at one wing, then at the other. Keep them parallel to the horizon. This plane has just left the deck of a naval airplane carrier.

the propeller utilizes the body of the plane; and the pressure of the spinning propeller tends to throw the plane into a slight rotation in the opposite direction. To help counteract this tendency, the ship is constructed so that the angle of incidence of one of the wings is less than that of the other. Also, the fin is sometimes

set at a slight angle, to obviate the need for constant pressure of the foot against the rudder-bar.

Since the effect of the torque and of the slipstream on directional stability varies with the speed of the plane, these proclivities cannot be entirely offset in the rigging of the wings. Therefore, at times there must be a compensating use of the controls to counteract these. Different planes require different degrees of pressure on the rudder and stick, which the pilot can soon determine by observing the action of the plane. Consequently, the continuance of the correct amount of pressure should become instinctive. Care must be taken to prevent overcorrection.

In order to keep the ship at the same altitude, you should place the nose so that it appears to be exactly on the horizon. When the nose deviates from the horizon, you should correct the deviation by gentle use of the elevators.

Handling the Controls in Straight Flight. In straight flight only slight movement of the controls is needed. Notice how slowly a lowered wing responds to the correcting movement of the stick. The stick must be moved quickly, although not far, to bring up a lowered wing. The ailerons are the least sensitive of the controls, since they are outside of the slipstream. The elevators are more responsive than the rudder, being purposely made so by providing them with a broader surface. Should the stick be thrust forward with a jerk, the plane would be thrown into a steep dive and you would be tossed forward in your seat, against your safety belt.

Bumps. "Bumps" are caused by varying or conflicting air currents, and they cause the plane to lurch ahead and then to drop a little in the manner of an automobile which is going over a "thank you ma'am." Do not be disturbed by the presence of bumps, nor think that the pitch and toss of the plane are due to your poor maneuvering. As long as the plane maintains sufficient speed, they will not cause loss of control. When correcting for these "bumps," be sure to apply rudder and ailerons in proportion.

Path of Flight. The path of flight of a plane is its line of progress through the air. It has no connection with the ground.

The plane rarely travels exactly according to the direction in which the nose is pointing. Unless, for example, the plane is traveling at exceptionally high speed, there is always a perceptible angle of attack which causes the nose to point slightly upwards; and unless the plane is traveling exactly with or against the wind, there will be drift to one side or the other. The student must learn how to estimate the effect of the forces which act to deflect the plane from its direct course.

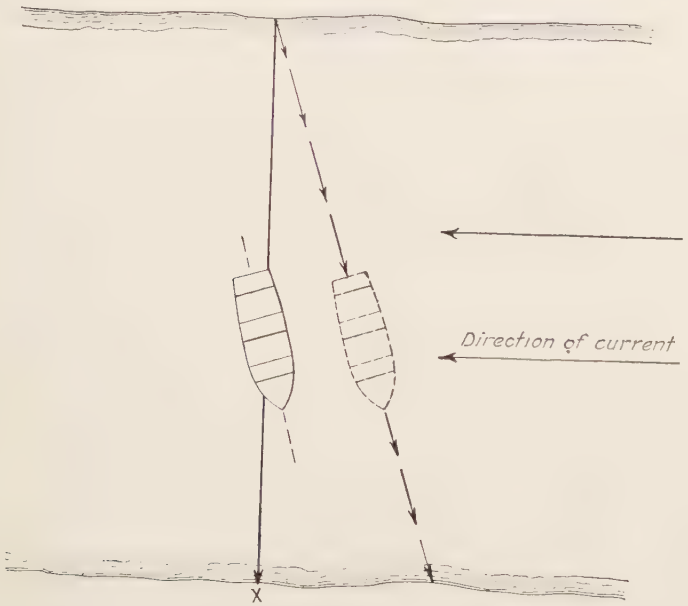


FIG. 95. HOW ALLOWANCE IS MADE FOR LEEWAY BY A BOAT, WHEN CROSSING A RIVER

Point x is the spot to be reached on the opposite bank. The dotted line shows the direction in which the bow must be pointed in order to hold the course indicated by the solid line, i.e., the course "over the ground."

The path of flight has an analogy in the boat's course through the water. The course of a boat through the water is distinct from its line of progress over the "ground." In Figure 95 the dotted line shows the course through the water which the boat must take in order to cover the ground indicated by the solid

line, and in order to reach the point x on the opposite bank of the stream. The distance between the solid and the dotted line is the amount of *leeway* which the boat must allow for.

The atmosphere, like the water, has a movement of its own over the surface of the earth. Just as the boat has to allow leeway,

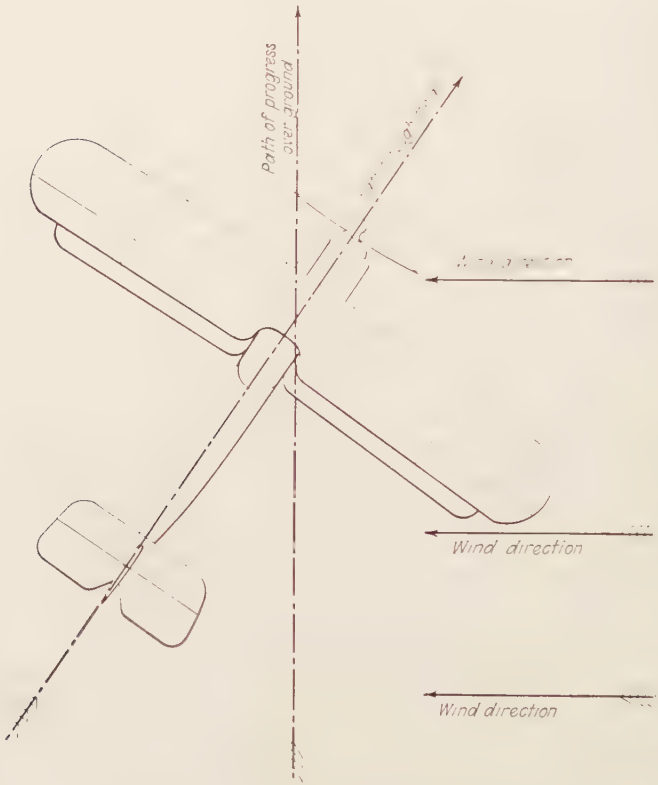


Fig. 96. Crabbing

In order to correct for drift, the ship must be headed a few degrees to the right of the direction over the ground which the pilot wishes to follow. In this way, he allows for the cross-wind.

and as the sight on a gun has to be set to one side to allow for a cross-wind, so the pilot must regulate his course in accordance with the "drift" of the plane brought about by the wind. If a

pilot desires to fly due west, and a north wind is blowing, he must point his craft in a direction somewhere between north and west, the exact point depending on the strength of the wind and the speed of the plane. Or, if he wishes to set his course in the direction of a tree which stands out on the horizon, and a strong wind is coming from his right hand, then he must point the nose somewhat to the right of the tree. When there is wind enough to cause the plane to drift, the plane appears to be going sideways, as a crab does. Therefore, in straight flight, the heading of a plane in one direction is called "crabbing." Figure 96 illustrates how the plane should be steered in order to correct drift. The principle involved here should be thoroughly understood. It plays an important part in navigation, and is further discussed in the chapter on that subject.

Just as there tends to be a horizontal difference between the path of flight and the direction in which the nose is pointing, due to the wind, so there tends to be a vertical difference due to gravity. An angle of the plane in relation to its path of flight is brought about only when, due to loss of speed, the lifting force is less than the force of gravity. Do not suppose that the plane is actually traveling in the direction in which the nose is pointing, unless the plane is running at a sufficiently high rate of speed. (See Figure 97.) When the speed is below flying speed, the direction of the nose is not in a line with the path of flight. Since the nose points high, you might easily be deceived into supposing that the plane is climbing when actually it is stalling. This illustrates the importance of watching your speed, and ascertaining that it is sufficient to maintain the flight of the plane, whatever attitude it takes in relation to the earth.

* * * * * * * *

Straight flying is simple in theory. But, in actuality, the smooth handling of the controls requires great skill and practice. If you have any doubt of this, examine Figure 98. It is essential that you become entirely accustomed to the "feel" of the controls and that you master their use in straight flight, before you attempt more difficult maneuvers.

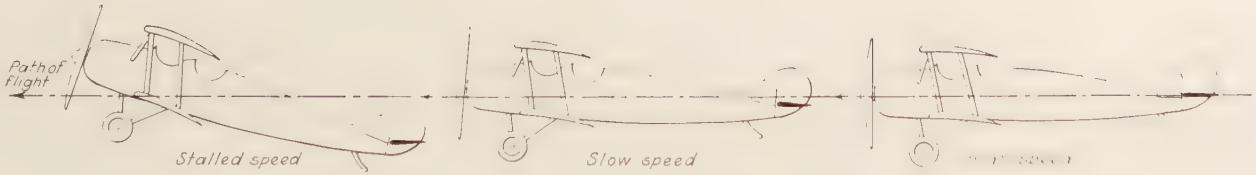


Fig. 97. Position of the Plane Versus Path of Flight

At high speed, the ship's longitudinal axis coincides with its path of flight. As speed decreases the latter is at an angle to the former. This angle increases, until the stalling point is reached.

Five Things to Remember about Straight Flying:

1. Anticipate fluctuations of the ship's nose, and correct for them in advance.

Sport & General Press Agency, London

FIG. 98. A TEST OF SKILL IN STRAIGHT FLYING

To maintain a perfectly straight course in an airplane calls for an extreme degree of skill. But such skill may be acquired—by continued practice. A fleet of British "Moths" in straight formation.

2. Do not overcontrol.
3. Allow for deflection from your course by a cross-wind.
4. Keep your nose on the horizon!
5. Keep flying speed: fly fast!

SUGGESTIONS FOR READING ON STRAIGHT FLYING

JONES, BYRON Q., *Practical Flight*, chap. XXIII. Ronald.
STUDLEY, BARRETT, *Practical Flight Training*, chap. XIII. Macmillan.
LE PAGE, W. L., *A. B. C. of Flight*, chap. V. Wiley.

QUESTIONS FOR REVIEW

1. Define straight flight.
2. What reasons may be advanced for teaching turns before teaching straight flight?
3. What considerations should govern the altitude for practice flights?
4. How is the pilot to know whether he is flying straight?
5. How is one to know whether lateral balance is being maintained?
6. Why must rudder and aileron be applied simultaneously?
7. Why does an airplane tend to turn to the left?
8. What causes "bumps"? How should they be met?
9. Explain crabbing. Of what importance is it in making cross-country flights?
10. What are the important things to remember about straight flying?

CHAPTER XI

TURNS

Any change in the horizontal course of the plane is a turn. Turns are accomplished by combined use of the rudder and ailerons. They are essential for any flying, even for straight flight. They must be practiced until the student automatically performs the necessary movements of the controls.

Elements of a Turn. In order to effect a turn, the rudder is used to swing the nose sideways. Bank is necessary to counteract the action of the centrifugal force, i.e., in order to prevent skidding. Throughout the turn, the action of the ailerons and the rudder should be simultaneous and coördinate. The turn may be divided into three parts: going into the turn, staying in the turn, and leaving the turn.

In order to go into the turn, move the stick sideways and the rudder-bar ahead, in the direction of the turn. (See Figure 99.) Since the plane tends to continue turning after the start, a slight relaxation of the ailerons and rudder may now be necessary, to prevent too tight a turn. To leave the turn, apply opposite rudder and opposite aileron.

Use of the Elevators in a Turn. It is highly essential that the nose be kept down on the horizon during a turn. Banking lowers the speed of the plane, and if the ship is allowed to climb, flying speed may be lost. The resulting stall would be dangerous, because the banked wings would hasten the bringing on of a spin.

To sum up, make sure that the nose is on the horizon before you start to turn. It is better that the nose be dropped below the horizon, than that it be allowed to climb. But the perfect turn requires neither a rise nor a drop.

Use of the Rudder in a Turn. The rudder-bar is always pushed in the direction of the turn to be made. For example, to start the plane turning to the right, apply right rudder. Because

of the torque, slightly more right rudder is required than is necessary when making a corresponding turn to the left. After you are in the turn ease the rudder-bar back slightly, since more rudder is required to start, than to keep the plane turning. To come out of the turn, apply a little opposite rudder to stop the

Curtiss Flying Service

FIG. 99. A TURN

In order to effect this turn the stick and rudder-bar were pushed slightly to the right.

turn, and straighten out the line of flight. Then centralize the rudder.

The rudder is a difficult control to handle. While the nose can always be placed on the horizon, and the lower wing can be held at a given distance below the horizon for a given angle of bank, there is no way of determining how much rudder should be applied in order to make the turn and the bank proportional. Only practice can train you to use the rudder correctly. (See

Figure 100.) The rudder may also be used to check slips and skids. A sideslip is apt to occur when you are going into the turn. You will recognize this by a blast of air on the inner or lower side of your face. Correct it by applying more rudder. A skid is made evident by a blast on the outer or upward side of your face, and may be corrected by removing some of the pressure on the rudder-bar. (See Figure 101.) Skids are very dangerous, because they decrease the speed of the plane and because they induce spins. Be sure to check them as soon as they begin.

Use of Ailerons in Turn. More aileron than rudder is used in turning. Like the rudder, the stick is moved sideways in the

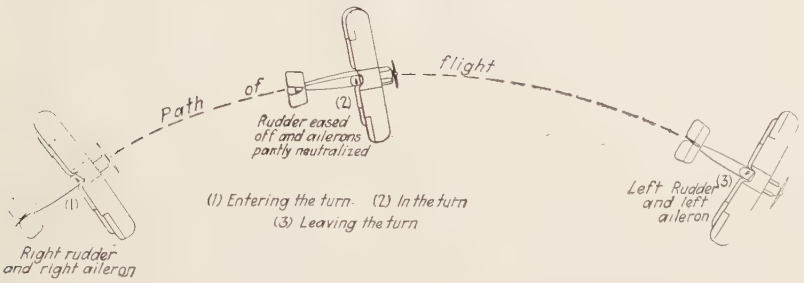


Fig. 100. Use of Rudder and Aileron in a Turn

This plan view of a right turn shows how rudder and aileron are applied strongly at the beginning of a turn, eased off during the turn, and the action reversed to come out of the turn.

direction of the turn. To go into a right turn, move the stick to the right in order to bank the plane. When the turn has begun regulate the steepness of the bank with the stick. The outer wing describes a wider arc than the inner wing; since the outer wing has to cover more ground during the turn than the inner wing, it travels at a higher rate of speed; therefore, it has more lifting power. The inclination of the plane is thus to go into a steeper bank. The amount which the stick must be eased back in order to keep the angle of bank constant depends on the velocity of the plane, the sharpness of the turn, and the strength of the torque. To leave the turn, push the stick up until the wings are level; then centralize it. (See Figure 100.)

It is best to practice turns requiring a 20 or 30 degree bank

during the first few hours. Flatter banks are difficult for the novice to achieve, without skidding. Banks steeper than 45 degrees involve the principle of "reverse control" flying, and should be avoided until proficiency in simple maneuvers is attained. The

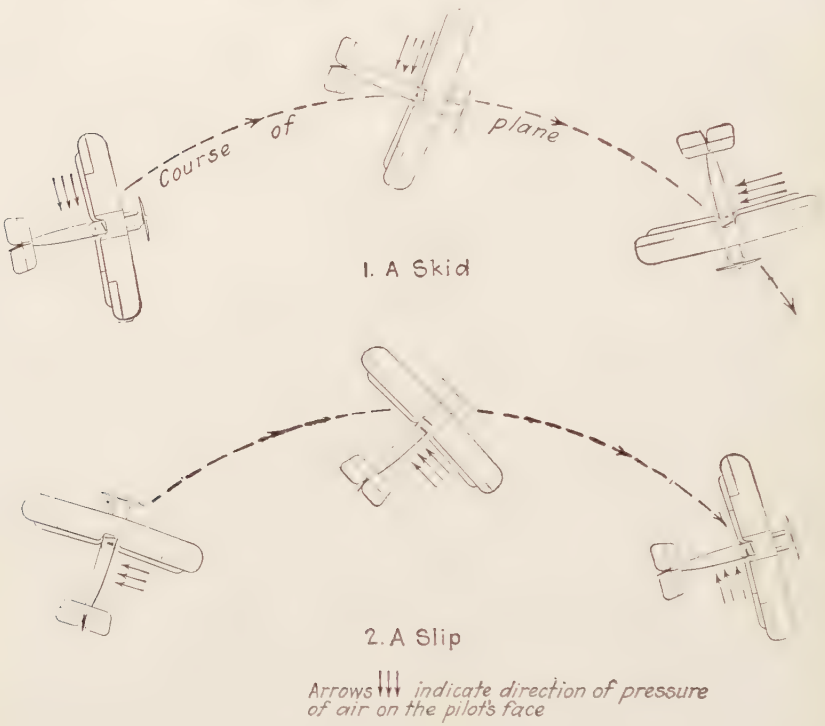


Fig. 101. Slips and Skids

In a right turn, too much bank causes the plane to slide, or *slip*, inward to the right, while too little bank causes it to slide, or *skid*, outward, to the left.

instructor will tell you how far below the horizon the lower wing should be for a moderate turn. In coming out of the turn, the bank should be reduced gradually as top rudder is applied so that by the time the wings are level the nose is also pointed straight on to the horizon and has ceased to turn.

S-Turns. An S-turn is a turn in one direction, immediately

followed by a turn in the opposite direction, as illustrated in Figure 102. It involves no new principles, but is simply a good means of practicing ordinary turns. To prevent the movement of the plane from being jerky, do not hold the stick and rudder in neutral

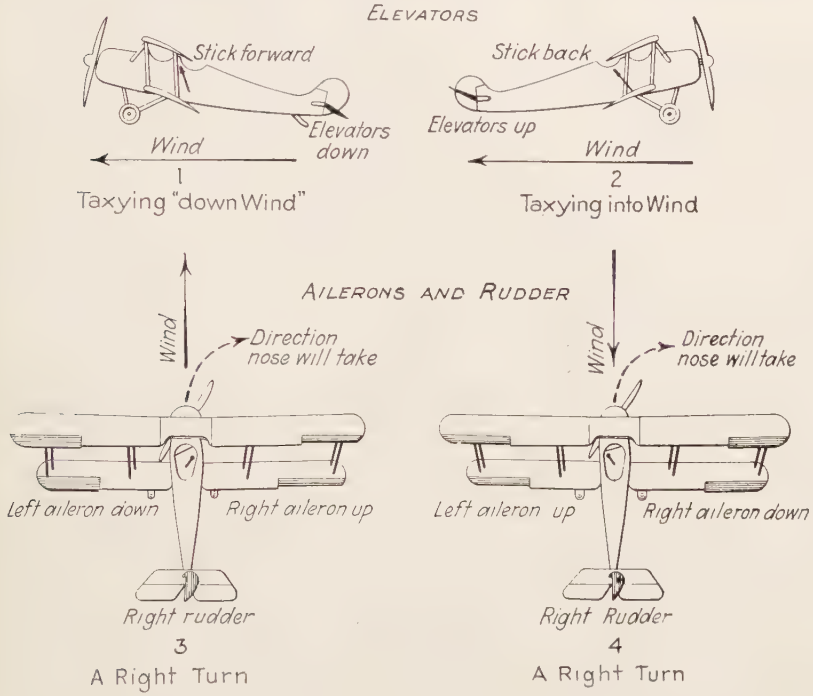


FIG. 102. USE OF CONTROLS IN TAXYING

In taxying, the operation of the controls is quite different from their use in the air. The rudder is simple enough, while the elevators are not difficult; but the ailerons must be operated so that the wind, impinging on their surfaces, will help to bring the ship around.

at the end of the first turn, but swing the controls over immediately but gradually into the next turn. On having learned to do an S-turn you are practically ready for figure eights. By following marks on the landing field you can get a great deal of practice in making turns with precision and accuracy.

* * * * * * * * *

Be sure to look around you before starting a turn. It is unwise to attempt any maneuvers if another plane is close to you.

You may be able to make turns more easily in one direction than in another. If this is true, take care to overcome this one-sidedness, as you might find it a great drawback in later flying.

If, at any time, you fear that you are losing control of the plane, discontinue the turn in order to regain speed. To do this, apply up aileron and top rudder, thus neutralizing the controls, and dive the ship. If the loss of control is due to skidding, apply the rudder more firmly; if to slipping, release it, so that the heading of the plane is brought into line with the path of flight. Drop the nose a little to gain speed. When balance is regained, neutralize the controls.

Four Things to Remember about Turns:

1. Use rudder and bank simultaneously and coördinately.
2. Keep your nose on the horizon.
3. If you feel a blast of air coming in from one side of the ship, push the stick to the other side.
4. Keep flying speed: fly fast!

SUGGESTIONS FOR READING ON TURNS

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Le Page, W. L., *A. B. C. of Flight*, chap. V. Wiley.
Jones, Byron Q., *Practical Flying*, chap. XXIV. Ronald.

Questions for Review

1. Why must ailerons and rudder be used in straight flying?
2. Describe how turns are made. Into what parts may a turn be divided?
3. Compare the turn in flying with the turn made in bicycling.
4. How are the elevators used when making a turn? What is the most important aspect of their use?
5. How is the rudder used in the turn?
6. Explain how torque affects turning.
7. How do you recognize a slip? A skid? How do you correct for each?

8. Which do you consider more dangerous, a slip or a skid? Why?

9. Draw a diagram showing that the outer wing describes a wider arc than the inner wing. How does this fact affect the operation of the plane, when a turn is being made?

10. How are S-turns made?

CHAPTER XII

TAXYING

Taxying, or the rolling of a plane along the ground under its own power, is a subject of comparative simplicity. It is, however, of great importance, because taxying is necessary whenever a plane takes off or lands. Furthermore, it is often desirable to taxy the plane from the hangar to the point of the field from which the plane may take off most effectively.

Direction of the Wind. Taxying may be done with the wind, against it, or across it. It is not always possible, since your objective in taxying is to reach a certain part of the field, to regulate your course in regard to the wind. It is easier, however, whenever you are able, to taxy into the wind, because the ship, like a weather-vane, has a tendency to swing around until the nose points into the wind. Furthermore, the controls are most effective when heading into the wind, because the strength of the propeller blast is augmented by the force of the wind itself, and this reacts favorably on the controls.

The controls become most ineffective of all when the plane is taxying down-wind. This is due to two factors. In the first place, a tail-wind greatly offsets the effect of the slipstream. Secondly, the plane was built to go ahead; that is, the controls were so designed as to utilize on their surfaces the force of air resulting from the forward movement of the plane. If you are obliged to taxy in a tail-wind, remember to start to make any necessary turns long before you come near to obstacles, because of the great reluctance of the plane to respond to rudder-bar and stick. But if the wind is strong, it is preferable to avoid its full force on the tail by "tacking" slightly. The controls are more sensitive in a cross-wind than in a tail-wind.

Handling of the Controls in Taxying. Because of the low speed of the plane when taxying, the controls are less responsive

than when it is in flight. Therefore, all movements of the rudder-bar and stick during taxying must be comparatively sweeping. The ailerons, since they are outside of the slipstream, are less sensitive than the tail group of controls and are not normally used in straight taxying.

When starting to taxy, open the throttle a little, slowly. Then, as the plane gains impetus, draw the throttle back slightly. Do not taxy too fast, because the controls are not positive in their action, and the ship may get away from you. Ten miles an hour is the maximum speed for a student. Even ten miles an hour may be too great a speed if the field is soft or bumpy, or if there are many obstacles near your course. In a cross-wind, however, it is necessary to maintain great enough speed to counteract the sideways pressure of the wind on the tail. If, through any miscalculation, you come near an obstruction when taxying, do not try to make a sharp turn to avoid it. You might expect to effect a tight turn by opening the throttle wide, so that the vigorous slipstream would render the rudder more responsive. If you discovered, however, after you had opened the throttle, that you were unable to make as sharp a turn as necessary, you would not be able to stop the plane. The result would be, at least, a damaged wing. It would have been better, if the plane were light enough, to get out and lift the tail around. When you are taxying near bystanders or other planes, as a matter of courtesy you should go slowly enough not to blow dust into their faces with the blast from the propeller.

The function of the elevators in taxying is to keep a proper balance between the attitude in which the ship tends to nose over and that in which it exerts too much pressure on the tail skid. When taxying down-wind, hold the control column slightly forward so that the wind cannot get under the elevators. (See Figure 103.) Keep the stick neutral or back when taxying into the wind.

Making Turns. Both ailerons and rudder are used to make turns while taxying. The ailerons of a light plane are of little use; yet, if they are fairly broad, they may be employed. The principle on which they work on the ground is quite different from that on which they work when in the air. When you wish to make a right turn in a brisk tail-wind, you push the stick to the right

side, as in flight. This movement drops the left aileron. But no bank results, since there is not a sufficient current of air under the left wing to lift it. Instead, the wind meets the surface of the dropped aileron, tending to push that wing around to the right.

If you wish to make a right turn when you are taxying in still air or into the wind, however, you move the stick to the left.

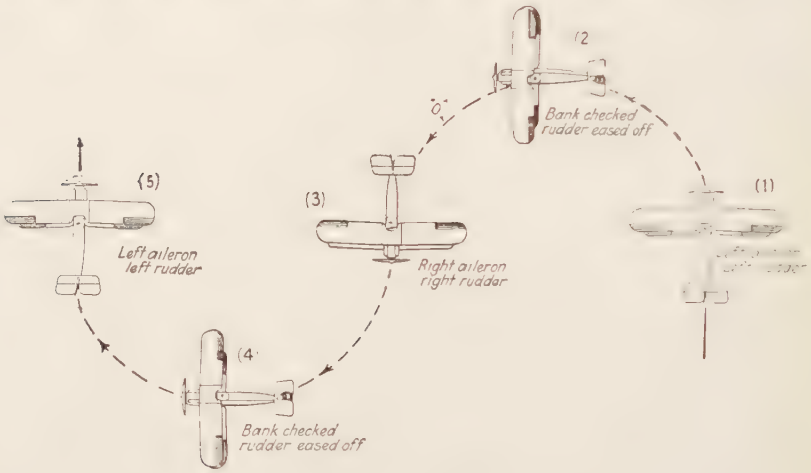


FIG. 103. AN S-TURN

This plan view shows how the controls must be used in order to make one turn immediately followed by a turn in the opposite direction. It must be realized that the moment when the controls are all centralized, approximately at point "O" between position (2) and (3), must not be prolonged. Thrust the stick and rudder-bar immediately into position shown in (3).

The right aileron, which drops, meets the resistance of the air, and drags. This *aileron drag* has the effect of a brake; the right wing becomes a sort of pivot about which the rest of the plane tends to turn.

In taxying across the wind, be sure not to let the wind catch one wing and throw the plane over on to the other. The moment enough wind gets under one wing to lift it slightly, the aileron on that side becomes effective, and a thrust of the stick in the direction of the raised wing will restore lateral balance.

The quickest way to make a turn is to have a man hold the

inner wing until the plane comes around. In this case, hold the elevators in neutral so that the tail skid will not drag.

The rudder is the most essential control in taxying. It is moved in the same direction to produce the same effects as in flight. To make a turn, apply full rudder at first; when the plane has begun to swerve, ease the rudder-bar back, to prevent too sharp a turn. Wide circles must be made in taxying, since tight turns are apt to throw the ship over on to the inner wing.

Ground Loops. A ground loop is a short turn on the ground, made in spite of the controls. Sometimes this tendency is caused by the location of the wheels too far forward or too far back on the fuselage. If they are too far forward the ground loop continues to grow worse after it starts; if they are too far back the plane will turn upon a wing or its nose. In either case, the wheels should be adjusted. Ground loops are most apt to occur, however, after landing, when the plane is not headed into the wind.

A ground loop should be checked immediately before the use of the controls is entirely lost and the sudden turn scrapes the outer wing on the ground. The rudder alone is unable to slacken the turn; therefore, you must open the throttle in order to cause a strong blast from the propeller. A strong slipstream will thus restore the responsiveness of the controls.

Handling the Plane on the Field. Before starting, you should make careful note of the obstacles in your path. Then plan your course so that you will not have to turn sharply in order to avoid them. In taxying, watch the ground ahead of you to avoid ditches, fences, holes, and other pitfalls. Swerve the plane slightly at intervals that you may see the ground obscured by the nose.

Taxying is extremely difficult in fields regularly used for flying, since planes are at any time apt to be landing or taking off. Even on an unused field, you should look about you to make sure that no ship is coming in to land, whose pilot might not see you because of the blind area in front of the nose of his plane. If you see an airplane coming in to land, stop and wait until it has reached the ground. Landing planes have the right of way over all others.

* * * * * * * * *

Taxying is a subject of comparative simplicity, but of great importance. You must be able to taxy in order to take off or to land. But it is a subject which has little similarity to the handling of the plane in flight, and, before your handling of the controls when in the air becomes instinctive, you should learn their use in taxying.

Four Things to Remember about Taxying:

1. Observe carefully the direction of the wind, which will greatly affect the control of the plane.
2. Handle the controls correctly. Their management in taxying is somewhat different from what it is when the plane is in the air.
3. Watch out for ground loops.
4. See that the field is clear. Landing planes have the right of way.
5. Keep flying speed: fly fast!

SUGGESTIONS FOR READING ON TAXYING

Jones, Byron Q., *Practical Flying*, chap. XIX. Ronald.
Swoffer, Frank A., *Learning to Fly*, chap. V. Pitman.
Clevenger, C. P., *Modern Flight*, chap. VIII. Alexander.

Questions for Review

1. Why is the operation of controls in taxying different from their operation when in the air?
2. Why is taxying easiest when heading into the wind?
3. Explain the use of the throttle in taxying.
4. Give three rules for avoiding obstacles when taxying.
5. Consult a pilot as to the operation of the elevators in taxying various types of airplanes.
6. How do you make a turn into a head-wind? Into a tail-wind?
7. How are the wings kept level in taxying?
8. What factors tend to make a ship ground loop?
9. How should a ship be handled in a ground loop?
10. What rules of air traffic should be observed in taxying?

CHAPTER XIII

TAKE-OFFS AND CLIMBS

A TAKE-OFF is the act of maneuvering the plane from the ground into the air. It is brought about by acquiring enough speed in rolling over the ground so that the lifting force of the wings is stronger than the force of gravity. You should begin to practice take-offs in the third or fourth hour of dual instruction.

Preliminary Inspection of the Plane. After each time the engine has been started afresh, and before taking off, you must make sure the plane is in all ways prepared for flight. The priming system should be off, and the spark advanced. Ascertain that the gas is flowing to the carburetor from the main tank, not from a reserve tank. Move the stick and rudder-bar back and forth to see that they are properly connected with the control surfaces, to be sure that the rigger has not crossed the wires so that the controls respond in a manner exactly opposite to their correct one. When the engine has run long enough to get warmed up and you have made sure that the brakes are on or that there are blocks under the wheels, hold the stick back and open the throttle wide for a few seconds. This will help you to detect any trouble that may exist in the engine, and to see that its speed mounts to its proper number of revolutions per minute. Since the stabilizer lever works in notches, you can tell by experience approximately at how many notches from the bottom to set it. (Sometimes the stabilizer is operated by a wheel instead of a lever.) The stabilizer may require further adjustment during the flight. The radiator shutters of water-cooled engines have to be opened wide for the climb, so that the engine will not overheat. Finally, you must remove the blocks from under the wheels, or release both brakes if your plane is equipped with them.

Choosing the Position for the Take-Off. When the plane is in readiness for the flight, taxy to the part of the field best

suited to taking off. It should be so situated that the take-off will be into the wind; and second, particularly in the case of a small field, it should allow the utilization of the longest dimension of the field.

Take off directly into the wind whenever that is in any way possible. The best take-off is one which gains flying speed at the lowest possible ground speed, thus covering the shortest possi-

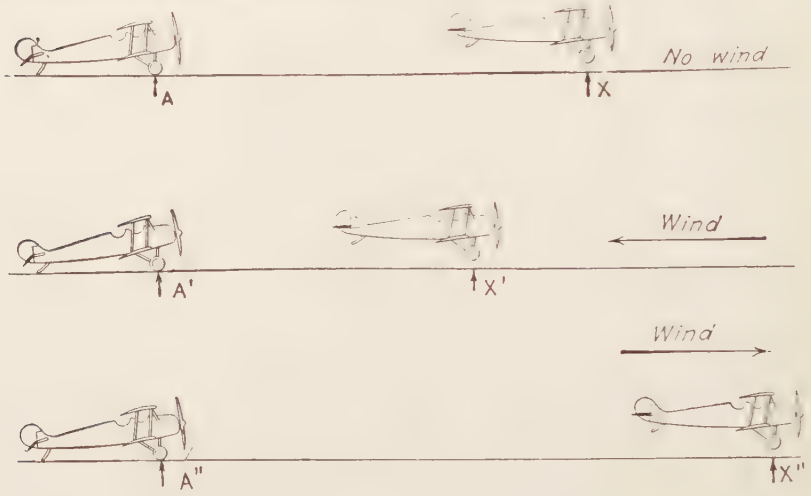


Fig. 104. Why You Should Take Off into the Wind

When there is no wind, the plane must travel from A to X before gaining enough speed to leave the ground. When taking off against the wind, it needs to travel only from A^1 to X^1. Taking off with the wind calls for a large field.

ble ground space. In order to do this, the plane must take off against the wind. If the plane is taking off into the wind, it will have the force of the wind against it, and thus its ground speed will be lowered. At the same time, the wind will exert its lifting force upon the wings and will increase the air speed of the plane. (See Figure 104.)

Unless the field is unusually long, it is important to make your take-off along its longest dimension whenever possible. In many cases the take-off might be successful, if begun halfway down the field. There is always the possibility, however, of engine

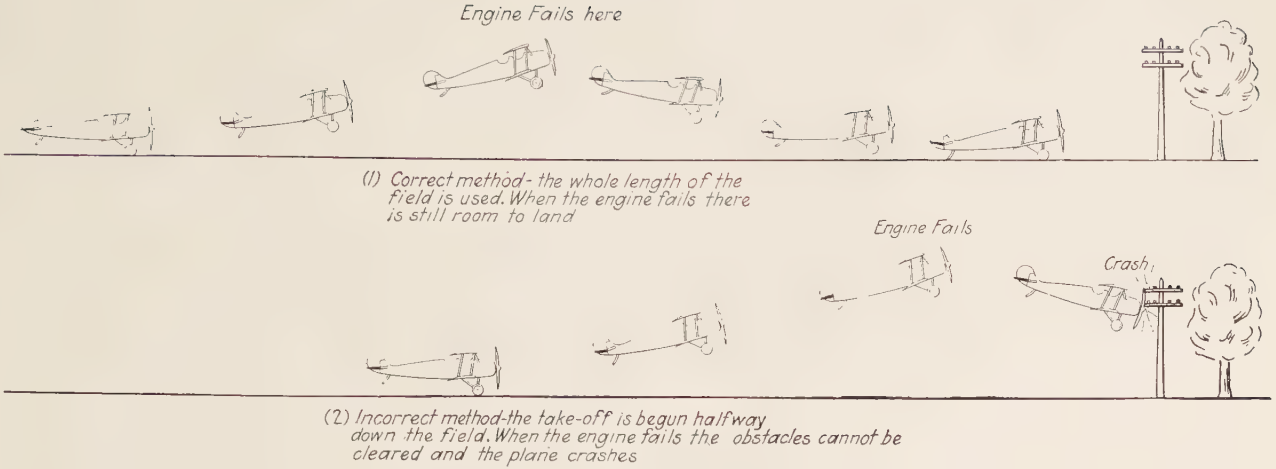

Engine Fails here
(1) Correct method - the whole length of the field is used. When the engine fails there is still room to land
Engine Fails
Crash!
(2) Incorrect method-the take-off is begun halfway down the field. When the engine fails the obstacles cannot be cleared and the plane crashes

FIG. 105. USE THE FULL LENGTH OF THE FIELD IN TAKING OFF

The student should maneuver his ship at all times so that engine failure at any instant will not find him unprepared.

failure. Engine failure does not necessarily result in a crash, if there is still a long run over the field ahead of you where you may land again. But if you have already passed the edge of the

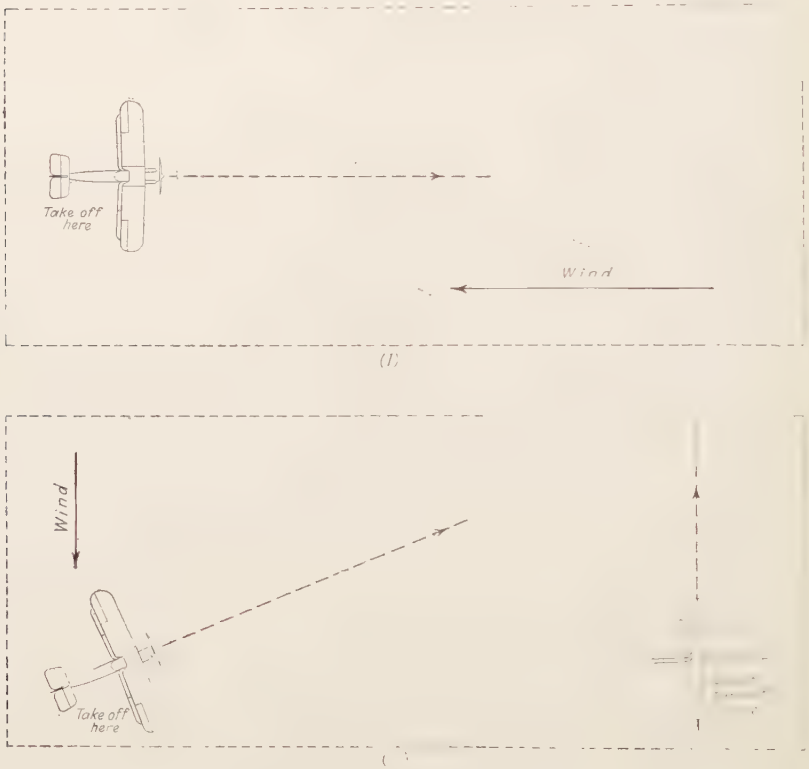


Fig. 106. How Best to Utilize the Field in a Take-Off

In (1), since the wind blows along the length of the field, you can without difficulty plan your course to use the long run of the field and take-off into the wind at the same time.

In (2), heading into the wind would mean allowing too little space in which to take-off. Therefore it is necessary to plan your course across wind as indicated.

field when the engine fails, you may not be able to clear any obstacles which may be outside of the field; or, if you attempt to turn back on to the field, the loss of speed occasioned by the turn may cause a stall. (See Figure 105.) When the wind does

not blow parallel to the length of the field, however, it is preferable to take off into the wind, if the field is sufficiently broad. If the dimension of the field which points into the wind is extremely short, you must take off across wind rather than run the risk of engine failure when the ground space is inadequate. (See Figure 106.)

Planning the Course for the Take-Off. When you have taxied to the position from which you will take off, picture your course half a mile ahead, so that you may avoid flying directly over high obstacles. (See Figure 107.) If you should head directly

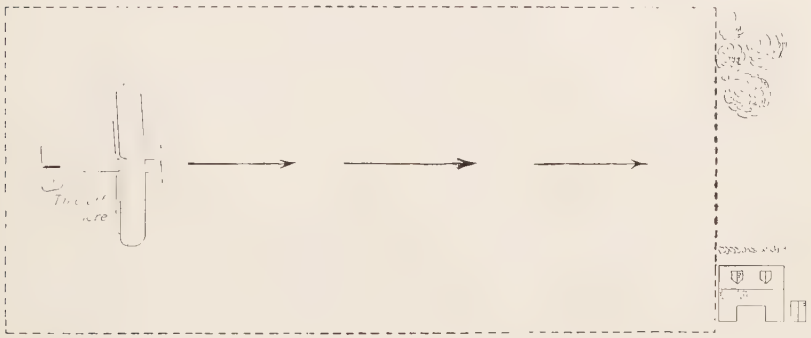


FIG. 107. AVOID TAKING OFF OVER OBSTACLES

Before "giving her the gun" point the nose of the plane in a direction which keeps you clear of obstacles; then steer a straight course.

toward a tree on the assumption that you would be able to fly over it, you might discover on approaching it that your speed was not sufficient to enable you to clear it. You would not be able to make a turn to go around it, however, without occasioning loss of speed. Therefore, acquaint yourself with the line of the horizon before opening the throttle to take off. Moreover, make sure before starting that no ship is taking off in a path which might converge with yours. Look about to see whether another ship is about to land. Remember that a landing ship has the right of way.

Leaving the Ground. When you have made sure that there are no obstacles in your path, you are ready to start the take-off. Taking off may, for purposes of explanation, be divided into two processes: first, leaving the ground; second, leveling off at the

height of a few feet above the ground. There are two methods of leaving the ground: one of them is "stalling off" and the other, which is the normal and preferable method, is that of letting the plane rise of its own accord when it has acquired flying speed.

Stalling off is necessary when taking off from ground which impedes the progress of the plane either by surface irregularities, deep grass, snow, or by other impediment. In stalling off, the plane is forced off the ground before it has reached flying speed, by pulling the stick back. Stalling off is used in order to get the plane off the ground as soon as possible. On such ground, more-

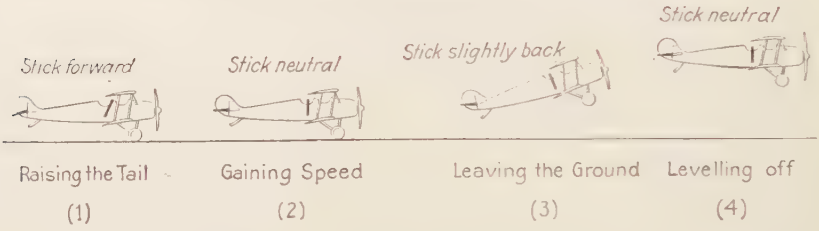


Fig. 108. Use of the Elevators in Taking Off

The stick is pushed clear forward at the start, in order to raise the tail, and is eased back slightly when leaving the ground. In leveling off, it is held in neutral position.

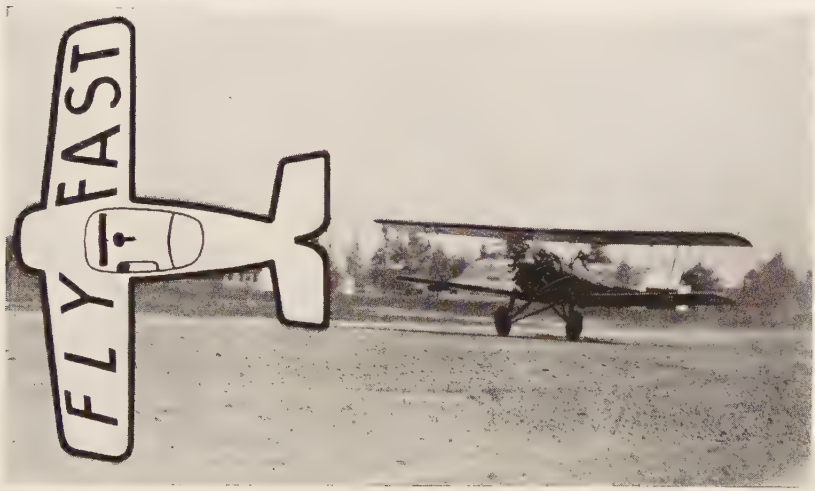
over, it is better to keep the tail fairly low as there is great danger of nosing over. Nevertheless, you will not be expected to stall off during your elementary lessons, if there is a smooth field available.

Leaving the ground in a normal take-off consists of three steps: raising the tail, gaining speed, and, finally, allowing the plane to come off the ground.

1. Open the throttle wide and keep it open wide throughout the take-off. Then push the stick away forward. As the plane begins to move ahead, the elevators become effective and the tail rises until the ship is in level flying position. (See Figure 108.) Throughout the take-off the rudder is used to hold the plane to its course. After this first step has been taken, no excessive movements of the controls should be made. They will have become

sensitive, and any hard, swift pressure on them will result in over-control. Figure 109 shows the start of a take-off.

2. When some speed is gained, the stick should be steadily eased back to neutral. This holds the ship level. If the stick is held too far forward or back, the plane's lifting power will not be at the maximum. Moreover, if the tail skid is permitted to drag, it will retard the ship's progress; if the stick is pushed forward,



Pitcairn Aviation, Inc.

FIG. 109. RAISING THE TAIL AND HOLDING THE SHIP LEVEL

This photograph shows the height to which the tail should be raised in order to give the greatest lift to the wings. The ship should be held in this position until sufficient speed is acquired to lift the plane from the ground.

the plane will nose over. You must hold the plane level until flying speed is reached. (See Figure 108.)

3. As soon as the speed of the plane has increased so that its lifting force offsets the force of gravity, the plane will usually take off of its own accord. (See Figure 110.) Unless the conditions are present which make it absolutely essential to stall it off, and unless you have become thoroughly proficient in taking off, do not attempt to pull the ship up by pressure on the elevators before it has reached flying speed. This forces the plane into the

Official Photograph, U. S. Navy

FIG. 110. LEAVING THE GROUND

When the plane has reached flying speed, it will usually leave the ground of its own accord. As soon as he gets up speed, therefore, the student should ease back slightly on the stick. In this case, the "ground" is the deck of a naval airplane carrier.

air under uncertain control, and there is great danger of stalling. When adequate speed has been attained, however, do not try to hold the wheels to the ground; fast rolling over the ground puts great strain on the landing gear. When the ship gives sign of leaving the earth, aid its movement by pulling the stick back slightly. (See Figure 108.)

Leveling Off. As soon as the plane has left the ground, bring the stick into neutral and hold the plane level for several seconds.

FIG. 111. LEVELING OFF

As soon as the plane has left the ground, it should be leveled off and held in this position for several seconds to gain speed. This is a Fokker plane flown by Byrd from America to France.

(See Figure 108.) You do this in order to gain speed, since the plane when it leaves the ground is traveling at a rate just barely in excess of stalling speed. The greater the field, the longer the plane may be held level. If the field is small, you are forced to start climbing sooner. Figure 111 shows a plane leveling off.

There are two cases in which the stick cannot be put into neutral the moment the plane is clear of the ground. One of these is the case of stalling off. Here the plane leaves the ground at an

Bellanca Aircraft Corporation

FIG. 112. STARTING TO CLIMB AFTER A TAKE-OFF

This photograph shows the gentle climb which should be used after a take-off so that the plane can gain speed.

appreciable angle to the horizontal, and the stick must be pushed forward immediately to prevent the slightest decrease in speed. Then hold the ship level with the wheels barely off the ground until sufficient speed is gained to start the climb.

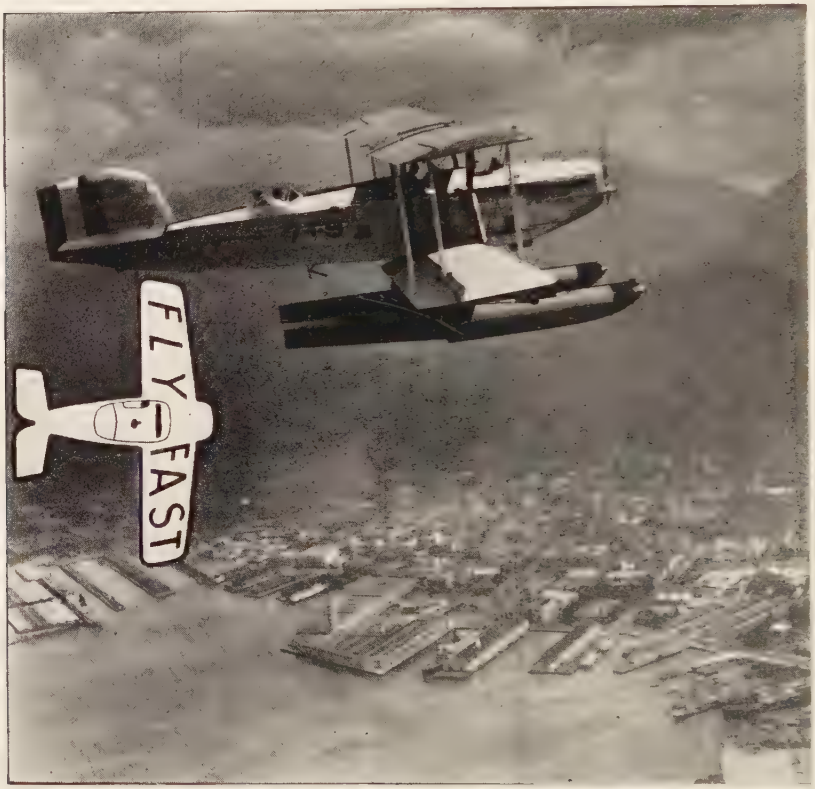
Whittelsey "Avian"

FIG. 113. TOO STEEP A CLIMB AFTER A TAKE-OFF

At this angle there is great danger of stalling the plane. Since it is practically impossible to prevent a crash when a stall occurs so near the ground, a steep angle of climb should never be attempted until sufficient altitude is reached.

The other case is one where the plane is forced off the ground by excessive irregularities of the field, before flying speed has been attained. In order to minimize the resulting stall in this instance, push the stick forward for a moment. Then pull the stick back to hold the nose level, and to prevent the wheels from

hitting the ground again. Hold the ship in this level position to gain speed.



Official Photograph, U. S. Navy

FIG. 114. A GENTLE CLIMB

The most efficient angle of climb is well below the stalling angle and as much above the horizontal as the engine will permit. Experiment alone will tell the best climbing angle. This ship is climbing over Honolulu Harbor. It is a Martin Torpedo and Bombing Plane.

Climbing. To climb is to gain altitude. When, by level flight directly above the ground, you have gained flying speed, then you commence to climb.

The instructor will show you where to point the nose in order to effect the proper angle of climb. (See Figure 112.) Too steep

an angle should not be attempted at the start of a climb from a take-off. (See Figure 113.) The speed of the plane is still near the stalling point, and must be increased. After a safe altitude has been attained, the angle may be increased.

The normal angle of climb is that in which the ship gains the most altitude without causing the engine to labor. It is somewhere between level flight and the stalling point. Its exact position between these two angles varies with the power of the engine, with the speed and direction of the wind, etc., and can be determined only by experiment. (See Figure 114.)

As soon as the plane is above the level of all the obstacles in its path, close the throttle a little. The excessive vibration of the engine at its maximum speed racks the engine and the construction of the plane. This lowered velocity is called "cruising speed."

In order to prevent overheating of the engine when an initial altitude of several thousand feet is desired, "step up" on the climb. By this is meant climbing a few hundred feet, throttling the motor as low as possible to maintain level flight until the engine has cooled off, and then climbing again.

Climbing Turns. Since more power is needed for curved flight than for straight flight, and since climbing turns tend to decrease the speed, they should never be attempted at this stage of instruction. For further particulars, see Chapter XV.

Instruments. Do not watch any instruments while taking off, but, when you are well advanced in the climb, watch your tachometer when reducing the speed of your engine, and glance periodically at the air-speed meter and at the altimeter.

Five Things to Remember about Take-Offs and Climbs:

1. Take off into the wind.
2. Plan your course to avoid all obstacles, before taking off.
3. Do not leave the ground until flying speed is reached.
4. Hold the plane level for a few seconds after leaving the ground, before you begin to climb.
5. Keep flying speed: fly fast!

SUGGESTIONS FOR READING ON TAKE-OFFS AND CLIMBS

STUDLEY, BARRETT, *How to Fly*, chap. XI. Macmillan.
CLEVENGER, C. P., *Modern Flight*, chap. X. Alexander.
SWOFFER, FRANK A., *Learning to Fly*, chap. VI. Pitman.
JONES, BYRON Q., *Practical Flying*, chaps. XX, XXI. Ronald.

QUESTIONS FOR REVIEW

1. Define the take-off and state what its elements are.
2. What duties does the pilot perform preparatory to the take-off?
3. Explain reasons for taking off into the wind.
4. Under what conditions is it necessary to take off in a cross-wind? When this is necessary, what precautions should be taken?
5. How should you plan your take-off?
6. How should the throttle be handled during the take-off? After the take-off?
7. Describe the use of the stick during the take-off.
8. Under what conditions does one stall off?
9. Interview two pilots as to how to determine the normal angle of climb.
10. Should the instruments be referred to during the take-off? Give reasons for your answer.

CHAPTER XIV

APPROACHES AND LANDINGS

Landing is the maneuvering of the plane from the air on to the ground. You will probably commence to practice landings in the four or fifth hour of dual instruction. Several hours must be devoted to the practice of landing the plane before you can expect to reach anything approximating the necessary proficiency. To land is the most difficult of all the elementary maneuvers, since a great degree of exactness is necessary.

Elements of Landing. A landing consists of a gliding approach to the field, leveling off over the field, dropping the plane on to the ground, and the rolling of the plane over the ground until it stops. The approach is for the purpose of losing altitude, and of turning the plane toward the field and into the wind. The plane drops to the ground when flying speed is lost, i.e., when the stalling point is reached. The pilot must bring the plane near to the ground before stalling, so that the drop will not cause injury. The steps in making a landing are shown in Figure 115.

Course of the Approach. Before starting to land, you should make a circuit of the field in order to plan every step of the maneuver. The course should be determined in accordance with four factors: the direction from which the field should be approached, the distance from the field at which the descent should be started, the obstacles in the air, and the obstacles on the ground.

1. The direction from which the field should be approached depends mainly upon the direction of the wind. A landing, should, whenever possible, be made directly into the wind. The slower the ground speed of the plane when it lands, the less will be the strain on the landing gear, and the sooner the plane will stop rolling, once it touches the earth. It is necessary to utilize the same fact that is considered in taking off, that when the plane is flying into the wind, the ground speed is equal to the air speed minus the rate

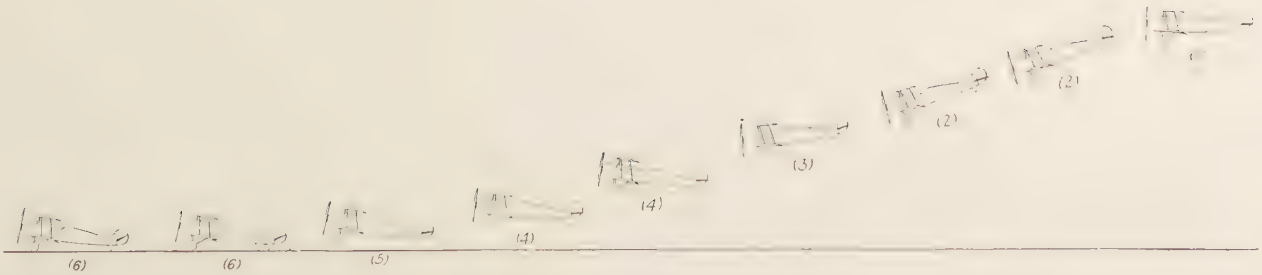


FIG. 115. STEPS IN MAKING A LANDING

1. "Cutting the gun"
2. Gliding
3. Leveling off
4. Losing speed and altitude
5. Stalling
6. Rolling over the ground

Fokker Aircraft Corporation of America

FIG. 116. WHICH WAY IS THE WIND BLOWING?

A difficult thing to learn is the various indicators of wind. The student must know the direction of the wind at all times. This calls for the closest vigilance. In the above picture there are at least three indicators of wind, plainly visible. Fokker Tri-motor over Moro Castle, Havana.

of the wind. The plane stalls when its air speed decreases to a certain point. If a straight approach is to be made, therefore, it

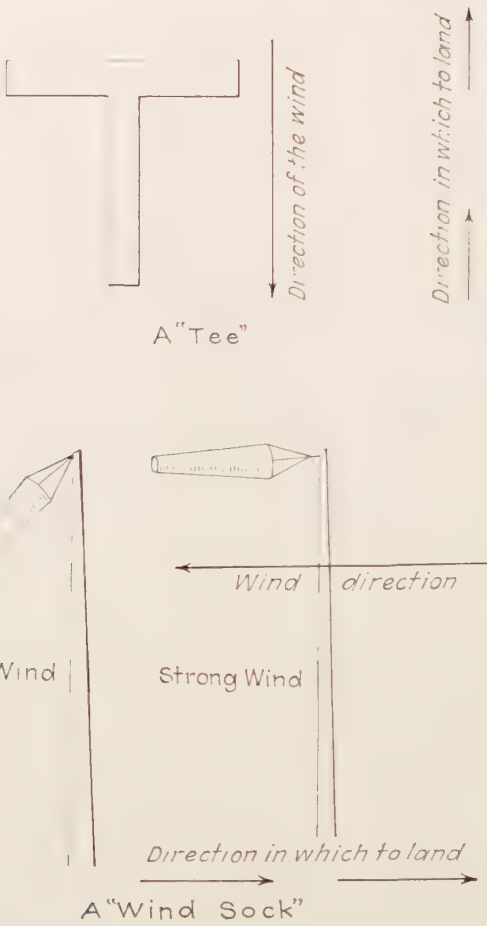


Fig. 117. Wind Indicators

The usual methods of showing wind direction on the flying field are by means of tees and wind socks. The tee can be seen farther but the sock gives an idea of the speed of the wind.

should be started up-wind, so that the landing itself will be made directly into the wind.

Many things may be used as wind indicators. (See Figure

116.) Most flying fields are equipped with both "tees" and "wind socks." A tee is a large letter T made from wood or other material and pivoted above the ground. Whenever the wind changes, a man whose duty it is to do so moves the tee around so that the stem on which the letter T would stand points in the direction towards which the wind is blowing. Sometimes the tee is operated by the wind itself. Since the position of the tee may not always be regulated promptly, it is better to check up on it by means of some other indicator. A wind sock is moved by the wind itself, so that it is always correct. It is often bright colored and positioned high enough from the ground to be easily seen. It is a funnel-shaped tube of cloth, several feet long, and attached by one end to a pole. It points in the direction in which the wind is blowing. (See Figure 117.) If you are landing in a field where there are neither tees nor wind socks, the direction of the wind may be indicated by trees, a grain field, clothes on a line, ripples on water, smoke from a chimney, etc. It should be borne in mind that smoke from a moving source like the stack on a locomotive does not necessarily indicate wind direction.

2. The distance from the field at which the descent should be started depends upon the speed of the wind. If the wind is strong, then the angle of glide may be steep without unduly increasing the ground speed of the plane, and the approach may be begun at a spot near the field. If, however, you are landing in dead air, the glide must be flatter in order to keep the ground speed low, and the approach must be started at a considerable distance from the field. (See Figure 118.) In the earlier stages of instruction, the plane should commence to glide at an altitude of over 200 or 300 feet.

3. When you have chosen the approximate position from which to start the approach, you must plan your course through the air and over the ground. Avoid setting the plane down directly beyond high obstacles; this would necessitate too steep a glide. Look around to see that there are no planes landing or taking off: although you have the right of way, you must avoid collisions.

4. The path of the plane over the ground should be planned so that there will be plenty of room on either side of the ship to allow for possible ground looping. Be sure that there are no

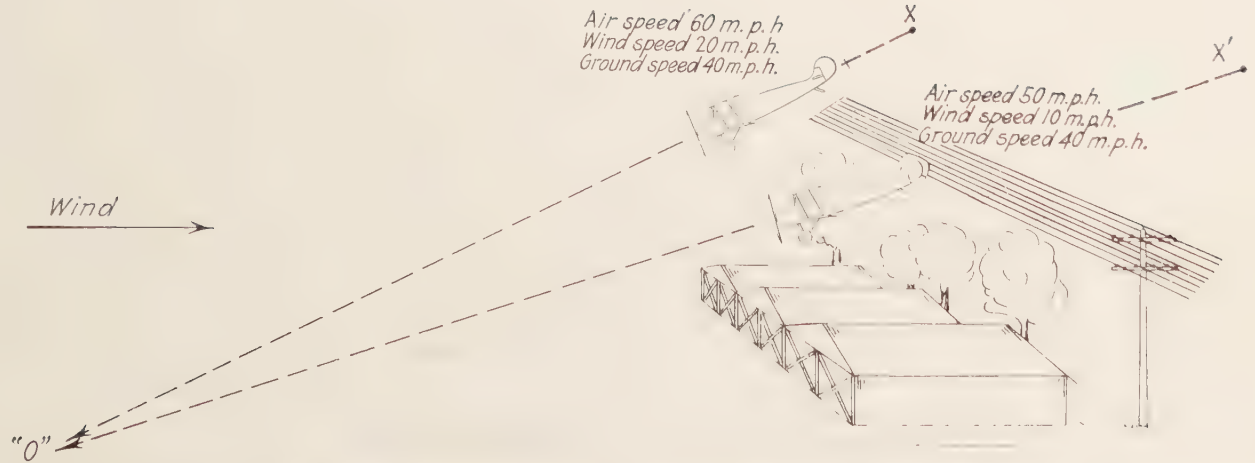


Fig. 118. The Speed of the Wind Determines the Distance from the Field at Which a Plane Must Start the Approach

In order to reach the earth at O at the ground speed of 40 miles an hour, the plane must start the approach at X in a twenty-mile wind and at X^1 in a ten-mile wind.

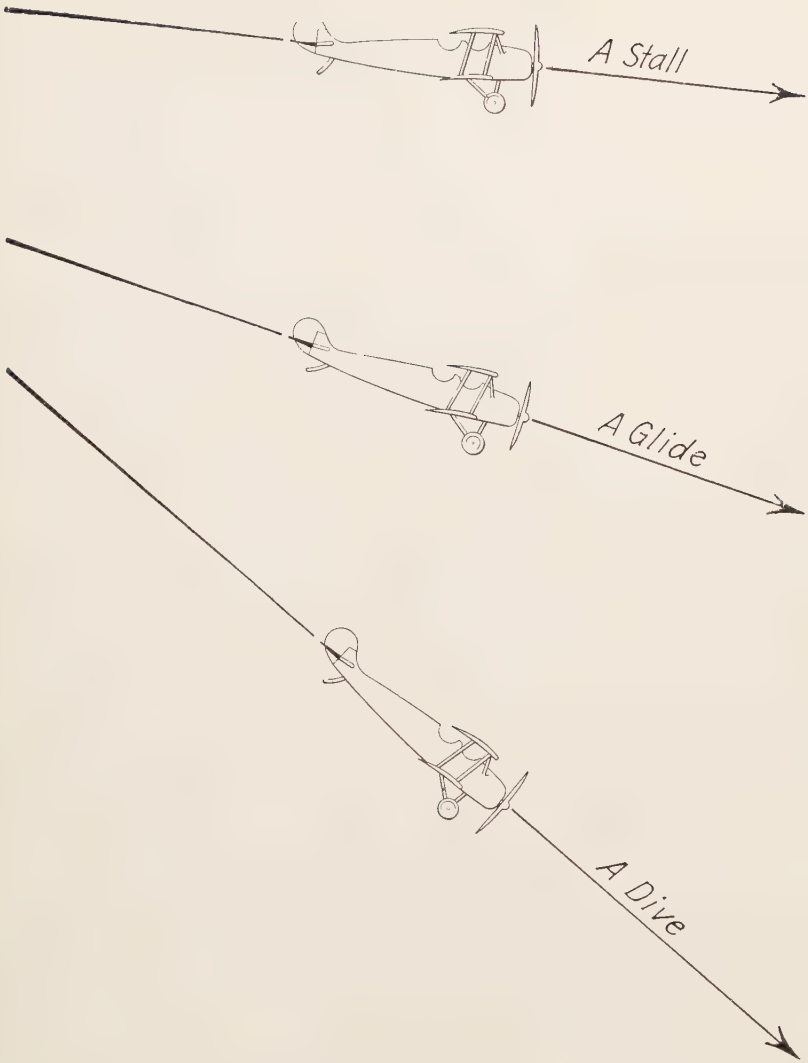


Fig. 119. Diagram Showing a Plane's Angle of Glide

These positions are only relative, since the normal angle of glide varies with the plane. A stall will occur when the plane is in horizontal flight if the engine is throttled.

obstructions directly in front of the landing place; the plane may roll farther than you expect. If other ships are taxying or taking off, take care that your path does not converge with theirs.

Gliding. When you have arranged the course you will take, "cut the gun," i.e., close the throttle, in order to begin the approach. An approach is effected by means of a glide. A glide is between a stall (which with a closed throttle is just under level flight) and a dive. (See Figure 119.) To glide is to fly with the engine throttled, by decreasing the angle of attack to such an extent that gravity, so to speak, takes the place of the engine. The purpose of a glide is usually to lose as much altitude as possible, at the lowest possible rate of flying speed. Therefore, the angle of glide should be sharp enough to prevent stalling, but not sharp enough so that excess speed is gained. The instructor will show you the correct angle of glide. Since a stall must be avoided at any cost, too steep a glide is better than too flat a glide. You will then be able to maintain the angle by keeping the position of the nose constant in relation to the horizon. Any change in the angle of glide may be detected by a variation in the pitch of the wires' humming. The plane's proper gliding angle with a throttled engine may be determined by raising the nose until a sideward sweep of the stick has no effect, and then by lowering it again gradually. As soon as the ailerons become responsive once more, the plane is in the normal gliding position. Do not make such a test at low altitudes.

If, when you near the earth, you find that you are going to over- or under-shoot the mark where you intended to ground the plane, do not change from the normal angle of glide. A flatter angle would result in a stall. A steeper angle would increase the ground speed of the plane, so that, once grounded, it would roll a long distance. (See Figures 120 and 121.) In the event of your over- or under-shooting very badly, the instructor will probably open the throttle and tell you to go around the field again. Another time you will be better able to judge the point from which to begin your approach in order to ground the plane at a desired spot without being obliged to increase or decrease the angle of glide.

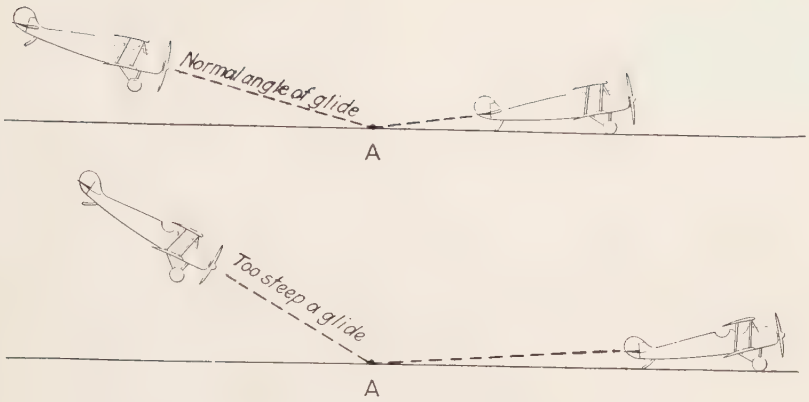


FIG. 120. OVERSHOOTING THE FIELD

Point A is the spot at which the pilot wishes his wheels to touch. The upper diagram shows landing as it should be made. In the lower diagram, the pilot has come too far over the field, and has glided at too steep an angle, so that he has not killed his speed with the result that the ship has rolled too far after grounding.

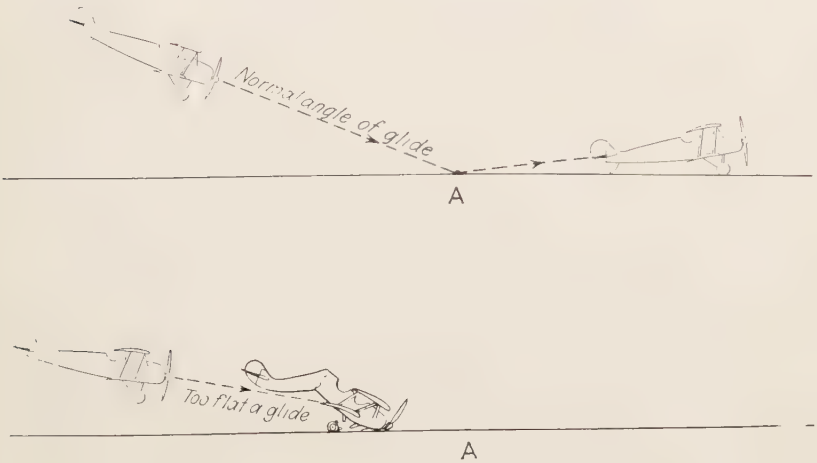


FIG. 121. UNDERSHOOTING THE FIELD

Point A is the spot at which the pilot wishes his wheels to touch. The upper diagram shows landing as it should be made. In the lower diagram the pilot has not come far enough over the field. He has attempted to "stretch out his glide." A stall is the result.

Leveling Off. When the plane is some 25 feet above the ground, it should be leveled off by a gradual backward movement of the stick. (See Figure 122.) Held in this horizontal position, the plane will lose speed. As speed decreases, the plane will sink nearer to the ground.

The Fairey Aviation Co., Ltd.

FIG. 122. THE SECOND STEP IN A LANDING: LEVELING OFF

The pilot of this plane has pulled the stick back, until at the altitude of about twenty-five feet the plane is level fore and aft. The plane will now begin to lose speed and to sink gradually towards the ground.

In order to estimate your height above the ground during the process of landing, do not lean over the edge of the cockpit; the shifting of your weight would make it harder to retain the lateral balance; moreover, altitude cannot be well judged directly from above.

Sit erect in the seat, and watch the ground one or two hundred feet ahead and a little to one side of the nose.

Stalling. As the plane loses speed, the stick must be pulled farther and farther back to keep the plane level. At last the stalling point will be reached, and to counteract the resulting nose-heaviness, the elevators must be raised as high as possible. (See Figure 123.) The plane should stall at an altitude of about 12 inches; a drop from 3 feet to the ground, however, will not be dangerous. When the plane stalls, and the stick is pulled away back, the plane will fall to earth at such an angle that both wheels and the tail skid touch the ground at once. This is called a "three-point landing." If executed accurately, this landing obviates the possibility of the plane's rebounding into the air.

Although correct use of the elevators is of prime importance in a landing, the other controls must not be neglected. The plane tends to drop one wing as it stalls. Any loss of lateral balance must be corrected immediately by coarse use of the rudder and ailerons. A lowered wing would probably be seriously damaged.

Since it is imperative that the throttle be used without hesitation in case of a bad landing, the instructor will probably not entrust it to you until you have had some experience in landing. You must be familiar with its use, however, so that you will be prepared to act quickly in case of need, when you are soloing. If the landing is poor (for example, if the plane approaches the stalling point ten feet above the ground), it is necessary to "give her the gun," that is, to open the throttle wide, and to go around the field for another landing. If, however, the landing is fairly good, you should carry it through for the sake of practice. Whenever you are obliged to open the throttle in order to discontinue a landing, open it instantly and fully. Sometimes, in the event of undershooting, the pilot gives the plane a momentary burst of speed, in order to bring it to the mark. You should not attempt this, until you have had considerable experience.

Rolling Over the Ground. After the plane has stalled to the ground, its operation is the same as in taxying, except that the greater speed must be allowed for. You must take extreme care to maintain lateral balance in order to prevent ground looping, as well as to hold a straight course. It is not safe to make use of the ailerons as in taxying until considerable momentum has been lost.

Curtiss Flying Service

FIG. 123. THE THIRD STEP IN A LANDING: STALLING

This plane, having come within a foot of the ground, has just reached a stalled position. In order to prevent the nose-heaviness consequent to a stall, the pilot has pulled the stick back. The raised elevator can be seen in the picture.

Faults in Choosing Position from which to Start the Approach. Pupils are apt, after having made one landing and gone around the field to make another, to take it for granted that the wind has not had time to change. Such assumptions are dangerous, as the wind has been known to turn 180 degrees within the time it takes to make the circuit of the field. Therefore, be

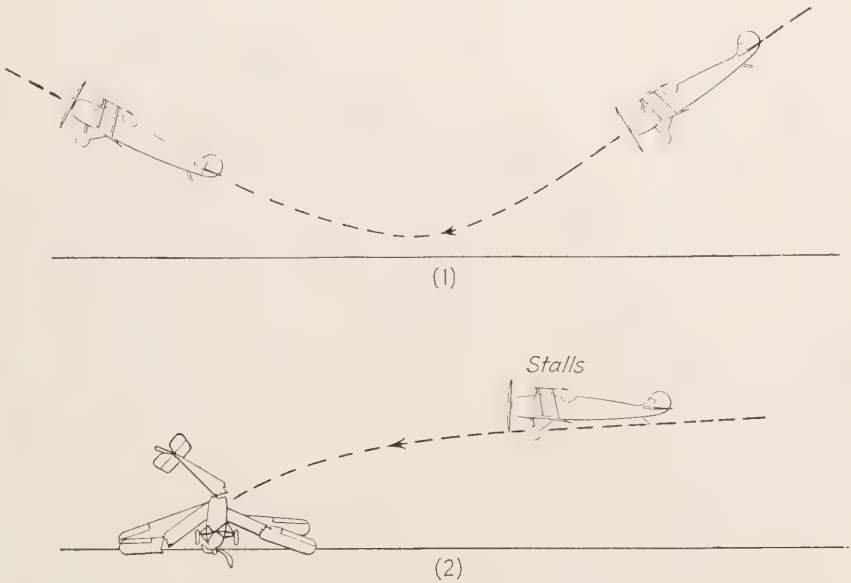


Fig. 124. Faults in Gliding

(1). Too steep a glide. The plane gains so much speed that when the stick is pulled back it climbs again.
(2). Too flat a glide. The plane stalls.

sure to glance at the wind indicators each time you are about to cut the gun to land.

The point at which you start to glide will determine to a great extent the mark where you will finally ground the plane. If this starting point is too far or too near the field, you will probably under- or over-shoot the mark. This point cannot be determined exactly, however, if a straight glide to the field is to be made, since the speed of the wind cannot be accurately calcu-

lated. For this reason, spot landings are not normally effected by means of straight glides.

Faults in Gliding. When the glide is begun, the student frequently fails to throttle the engine and apply forward movement of the stick simultaneously. Great care should be taken not to commit this error. It should become a habit to push the stick forward whenever the engine stops. If the elevators are lowered while the engine is still running at full speed, excessive momentum will be acquired. If the throttle is closed before the stick is pushed forward, speed will be lost, and there will be danger of a stall.

Too steep or too flat an angle of glide must be avoided. Too steep a glide allows the plane to gain so much speed that when it is leveled off, instead of stalling, it will climb again. (See Figure 124.) Too flat a glide decreases the speed so that, when the stick is pulled back at leveling-off height, the plane is apt to stall. In this case, you must open the throttle wide at the first indication of a stall and go around the field again. (See Figure 124.)

Faults in Leveling Off. When you begin to level off at 20 feet or so from the ground, only a slight movement of the stick is necessary. If the stick is pulled back too jerkily or too far, a stall may result. (See Figure 125.) To avert this danger, take care to move the stick gently and gradually.

Sometimes, students fail to level off at all. This is an error which is bound to result either in a crash, or in a "wheel" landing from which the plane will bounce or "porpoise" quite high. (See Figure 125.)

Faults in Stalling. A "tail-high" landing is of common occurrence. (See Figure 126.) This takes place when the student fails to pull the stick back far enough. The plane lands on its wheels, with the tail in the air before it has fully stalled. (See Figure 127.) Such a landing will have no disastrous effects on level ground; but, if the ground is uneven, the plane will bounce. If it bounces badly, open the throttle wide, so that the plane will not fall back too heavily on to the ground from the rebound; then push the stick forward slightly to bring the plane down again, and as the ship stalls, pull the stick sharply back. If the bounce from the tail-high landing is too pronounced, it is better to open the

throttle wide and make another circuit of the field for a new landing.

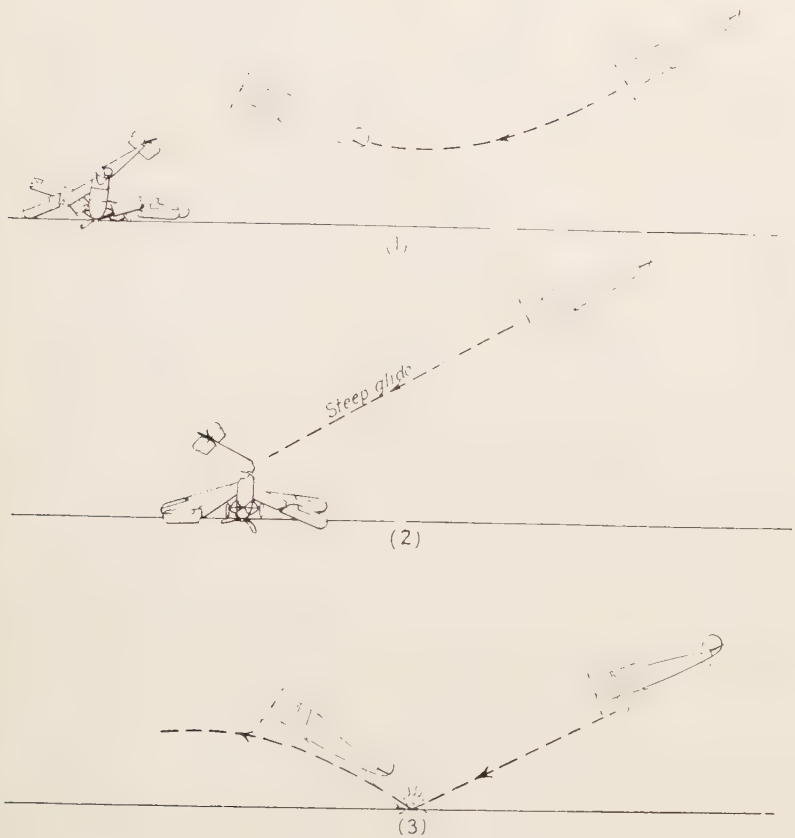


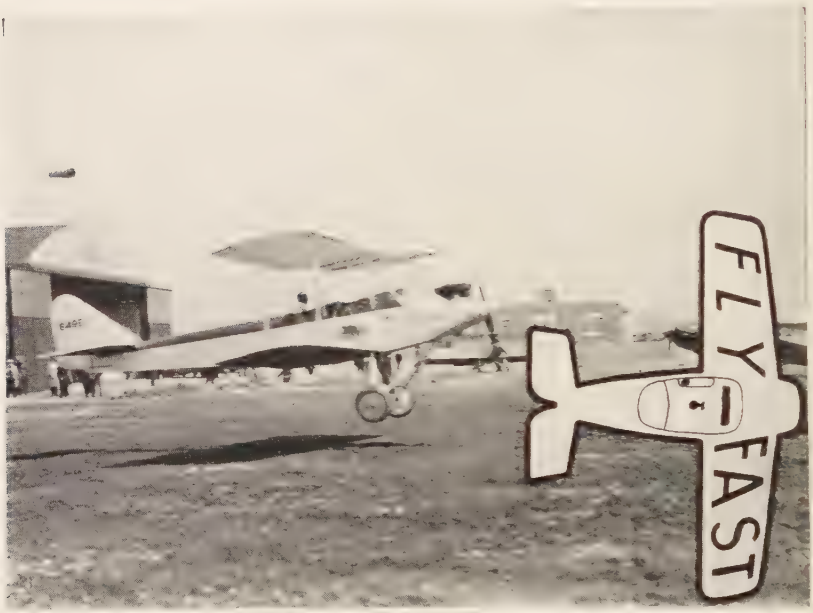
Fig. 125. Faults in Leveling Off

(1). Pulling the stick back too far. The plane stalls.
(2). Failure to level off at all. If this happens when gliding angle is very steep, the plane crashes.
(3). Failure to level off. If this happens when gliding angle is flat, the plane bounces.

A "pancake" landing is one in which the plane is allowed to stall too high in the air, so that it settles heavily on to the tail skid and wheels. Since this type of landing causes the plane a

great deal of strain, it should be avoided by opening the throttle as soon as the plane approaches the stalling point and by going around the field again. (See Figure 127.)

Other Types of Landings. Certain conditions necessitate a deviation from the regular method of making a landing. Other



Whittelsey Manufacturing Co., Inc.

FIG. 126. A "TAIL HIGH LANDING"

The pilot has neglected to pull his stick back far enough. The wheels will touch the ground before the tail, which will cause the plane to bounce off the earth again.

types of landings must be practiced before you fly solo, but you will not be given instructions in them until you have become familiar with the principles of a normal landing.

A "forced landing" is one that is made immediately necessary, either because of impending engine failure or because the engine ceases to operate. A "dead-stick" landing is one made after the motor has stopped running entirely. The "dead stick,"

or motionless propeller, offers so much parasite resistance that the glide must be considerably steeper.

When the plane is so high above the ground that it threatens to overshoot the mark, there are two methods by which height may be lost without gaining excessive speed. One of these is to sideslip. The other is to make a "fishtail" landing; that is, to skid the plane from one side to the other. These types of landings are further discussed in Chapter XIX.

Other Types of Approaches. A straight approach cannot be used to effect an accurate landing, since you cannot calculate

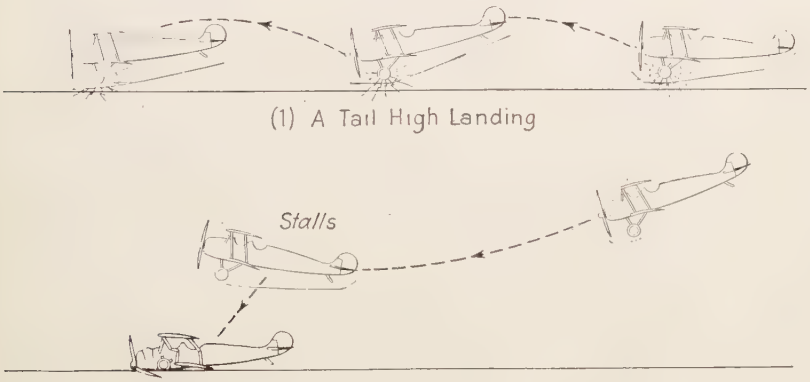


FIG. 127. FAULTS IN STALLING

(1). The plane landed before being fully stalled.
(2). The plane stalled when too high above the ground.

where you cut your gun in order to land exactly at a given spot on the field. Therefore, as soon as you have become somewhat accustomed to making landings, you will probably begin to use spiral and S-turn approaches. Either of these methods of approach allows the pilot to make the turn sharper or more gentle at any time that he sees that he will under- or over-shoot. A full description of them is given in Chapter XIX.

Six Things to Remember About Approaches and Landings:

1. Find out which way the wind is blowing before each landing.

2. Too steep a glide is better than too flat a glide. Avoid both.

3. When leveling off, do so gradually.

4. When grounding the plane, hold the wheels off until the tail is down.

5. Do not forget to control the plane after it is grounded.

6. Until you are ready to stall the ship, keep flying speed: fly fast!

SUGGESTIONS FOR READING ON APPROACHES AND LANDINGS

JONES, BYRON Q., *Practical Flying*, chap. XXIX. Ronald.
SWOFFER, FRANK A., *Learning to Fly*, chap. VII. Pitman.
CLEVENGER, C. P., *Modern Flight*, chap. XI. Alexander.

QUESTIONS FOR REVIEW

1. Define the landing and state what its elements are.
2. Why should you make a circuit of the field before landing?
3. How should your approach be planned?
4. Describe the commoner types of wind indicators.
5. How should the angle of glide be determined?
6. At what altitude should you level off?
7. Describe a three-point landing.
8. How should the ship be handled once it has touched the ground?
9. Interview a pilot as to what are the commonest faults in making landings.
10. What forms of approach are there, other than the straight glide? Explain their advantages.

PART FOUR

ADVANCED MANEUVERS

CHAPTER XV. CLIMBING AND GLIDING TURNS

CHAPTER XVI. STALLS AND SPINS

CHAPTER XVII. SOLOING

CHAPTER XVIII. REVERSE-CONTROL FLYING AND ACROBATICS

CHAPTER XIX. ADVANCED INSTRUCTION IN LANDINGS

By the time the elementary maneuvers come easy to the student, he will find the task of mastering the more advanced ones comparatively simple. To anyone who becomes really expert in the steps so far treated, proficiency in the remaining feats of aviation is merely a matter of practice.

Chapter XV explains how climbing and gliding turns are made, these following logically upon turns, glides, and climbs, as taught him in his earlier lessons. The second chapter in Part Four discusses what the author considers to be the most important single subject in flight training—that is, the subject of stalls. Next, soloing is treated, particularly the first few flights which the student makes by himself. Chapter XVIII describes the more important feats of acrobatic, or reverse-control, flying. The section ends with a discussion of landings under adverse conditions, a question which the wise instructor will not have let him dismiss from his mind for a moment, even from the start of his training.

CHAPTER XV

CLIMBING AND GLIDING TURNS

A CLIMBING or a gliding turn is merely the combination of a turn with a climb or a glide. Thus each of these maneuvers is effected by the union of the principles of two familiar operations. But, since these principles must be modified when they are combined, it is not usual for the instructor to delay teaching climbing and gliding turns until the latter part of the period of dual instruction.

Use of the Climbing Turn. A climbing turn is exceedingly useful, when you are taking off from a field surrounded by woods or houses, which may be the only available field in the vicinity. If you should follow a straight course during and after the take-off from such a field, you would leave the field farther and farther behind. Then, if engine failure should force you to land before you have gained any considerable altitude, your landing would have to be on whatever trees or houses may lie directly before you. On the other hand, if you should begin to turn soon after the plane leaves the ground, you would be able to reach the field by making a 90-degree turn, if the engine should fail at any point in the climb, except immediately after the take-off. (See Figure 128.)

How to Make a Climbing Turn. Both a climb and a bank decrease the speed of the plane. A maximum angle of bank combined with a maximum angle of climb would soon result in a stall. Therefore, a climbing turn must be effected by the most cautious movements of the stick and rudder-bar. Figure 129 shows a steep climbing turn. A steep climbing turn of 180 degrees executed soon after the take-off is known as a "chandelle."

To go into a left climbing turn (see Figure 130) pull the stick back slightly, bank the plane to the left, and apply left rudder. To stay in the turn, rudder and bank must be checked,

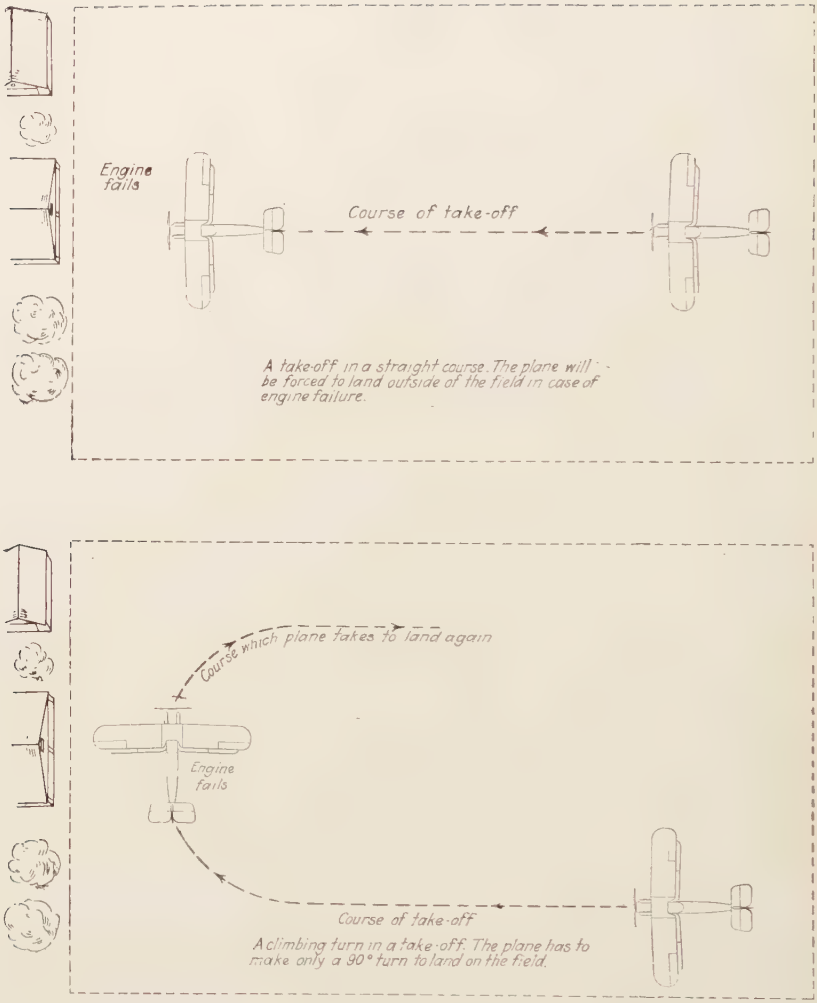

Engine fails
Course of take-off
A take-off in a straight course. The plane will be forced to land outside of the field in case of engine failure.
Course which plane takes to land again
Engine fails
Course of take-off
A climbing turn in a take-off. The plane has to make only a 90° turn to land on the field.

FIG. 128. THE ADVANTAGE OF A CLIMBING TURN IN A TAKE-OFF

If your field is located in a congested district, a climbing turn will enable you to get out of it with comparative safety.

as in an ordinary turn. To come out of the turn, employ right rudder and ailerons, and push the stick forward enough to bring

Flight

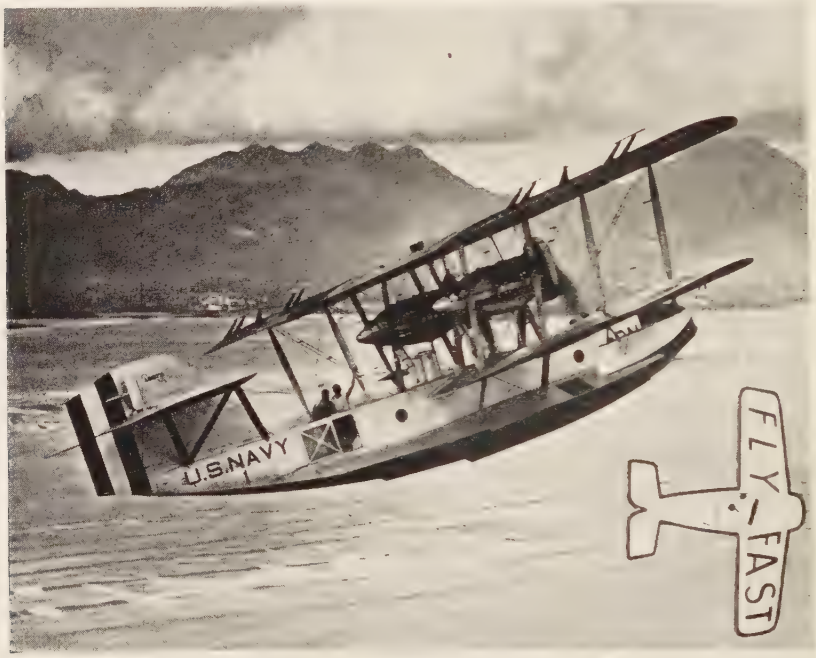
FIG. 129. A STEEP CLIMBING TURN

Such a turn directly after the take-off, is known as a *chandelle*. A chandelle brings you into a direction opposite to that in which you took off, and gains you considerable altitude. It is not a maneuver for a beginner. English Avro single-seater.

the nose down on to the horizon. When the plane has leveled off, centralize the controls. (See Figure 131.)

Use of the Gliding Turn. A gliding turn is ordinarily used to turn the plane into the wind preparatory to landing. A quarter

spiral (90 degrees), or a half spiral (180 degrees), may be made, according to the amount of turn the plane must make in order to nose into the wind. A series of gliding 360-degree turns, i.e., a complete spiral, or gliding S-turns, allow the plane to descend from considerable altitude while still flying over the landing field.



Official Photograph, U. S. Navy

FIG. 130. A SMOOTH CLIMBING TURN

When the turn is fairly sharp the climb cannot be steep, otherwise a stall will result, even when there is an ample reserve of power, as is the case here. This is Commander John Rodgers' plane over the harbor at Honolulu. (Note that position of control surfaces does not agree in the control diagram.)

Differences between a Gliding Turn and a Straight Glide. There is more danger of a stall when the glide is curved than when it is straight, since the bank causes a decrease in speed. This is true because the lift of the wings is less when they are slanted than when they are horizontal. Due to the rapid loss of

altitude, it is imperative that you begin to turn at a sufficient height so that you will not be too near the ground when the turn is complete. The last part of this approach should be a straight glide to the point of landing.

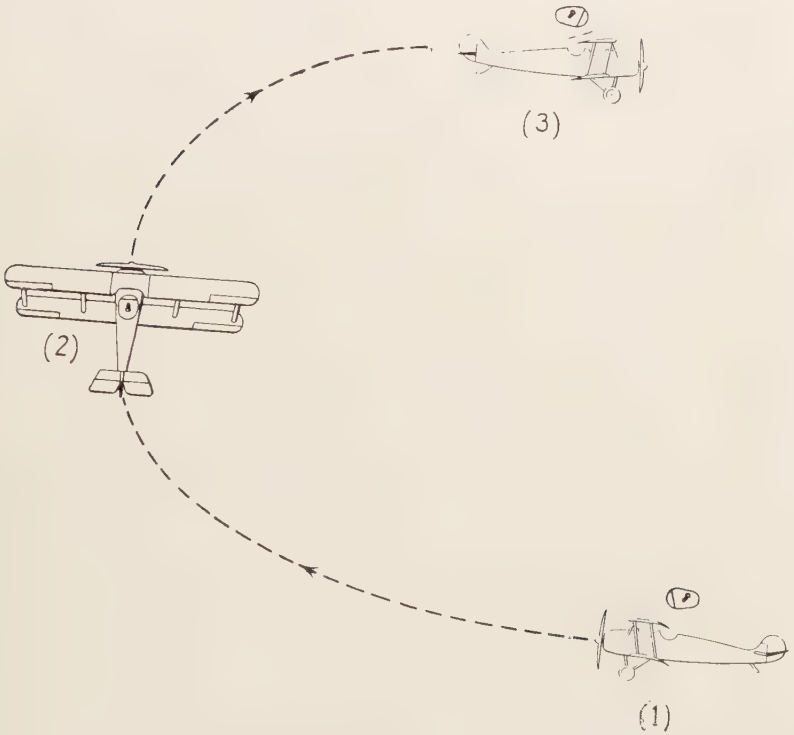


Fig. 131. Use of Controls in a Climbing Turn

(1). Going into the Climbing Turn
(2). Staying in the Climbing Turn
(3). Leaving the Climbing Turn

Differences between a Gliding Turn and a Turn in Level Flight. The throttling down of the motor for a gliding turn has several effects which do not occur in level flight. In the first place, there is great danger of stalling, unless sufficient angle of glide is maintained. Second, the decrease in force of the slip-

stream makes coarse movements of the rudder necessary in order to turn the plane. Moreover, the sluggishness of slipstream and of propeller revolutions eliminates the torque, so that no allowance need be made for the turning of the plane to the left. Since skidding and slipping are as common in gliding as in any other turns, rudder and bank must be applied proportionately.

How to Make a Gliding Turn. To go into a right gliding turn (see Figure 132), close the throttle, push the stick forward,

FIG. 132. A SLIGHT GLIDING TURN

To effect this turn, very gentle use of ailerons and rudder was necessary. The gliding turn is very commonly used in approaching for a landing.

apply right rudder, and bank the plane to the right. To stay in the turn, check the bank and the pressure on the rudder-bar, as in an ordinary turn; raise the elevators to neutral, as the force of gravity will hold the plane to a glide, and use the stick to keep the nose from dropping too low. Be sure, however, to keep flying speed. To come out of the gliding turn, open the throttle, pull the nose up, and apply left ailerons and rudder until the ship is level. Then centralize the controls. (See Figure 133.)

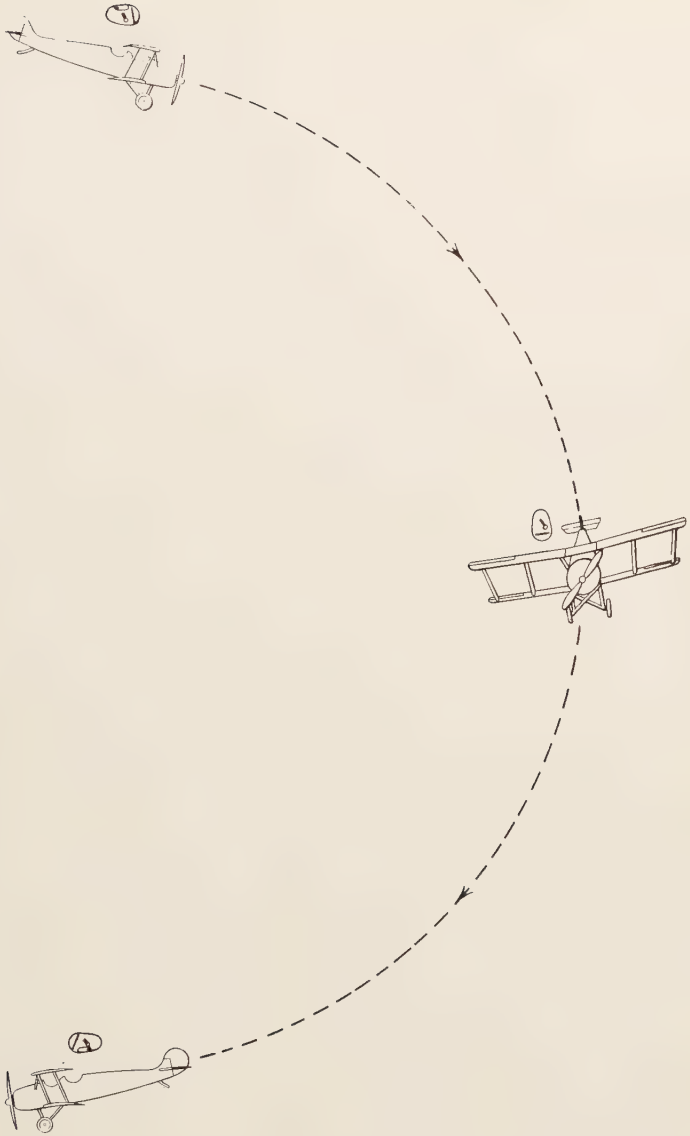


Fig. 133. Use of Controls in a Gliding Right Turn

In this, as in similar maneuvers, it is important to remember to ease off on the controls after the turn has been started. Most beginners make this mistake of overcontrolling the ship.

In order to make a spiral, hold the ship in the turn as soon as the bank and rudder are sufficient. Spirals of 180 and 360 degrees are commonly used in training pilots. To make a gliding S-turn, do not hold the ship level when the first turn is finished, but promptly, though gradually, go into the opposite bank.

Use of Gliding Turns in an Approach. As a means of approaching the field for landings, spiral or gliding S-turns have several advantages. They allow the plane to lose altitude while covering little ground space. By means of a spiral, a plane is able to land on a field almost directly beneath it, if the approach is made from a sufficient height. An S-turn approach enables the pilot to keep the field in sight throughout the glide; therefore it is useful for getting into a field surrounded by obstacles, where the air traffic is heavy, or where he is traveling down-wind and there is danger of overshooting.

When you use gliding turns in an approach, remember that the loss of altitude will be rapid. Start to turn at the beginning of the glide, if you are not too high up; the plane must be nosed into the wind before it gets too near the ground. The turn should always be straightened out before the leveling off for landing; any remaining bank when the plane lands may cause a wing to be damaged.

Five Things to Remember about Climbing and Gliding Turns:

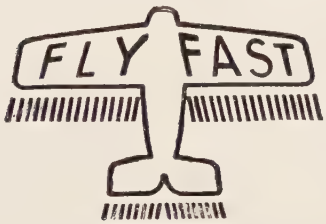
1. Move rudder and ailerons in proportion.
2. In climbing, do not turn too sharply; in turning, do not climb too steeply.
3. In gliding, start to turn at a sufficient altitude so that you will have time to complete it before you near the ground.
4. Don't fly the plane in a bank when you are close to the ground.
5. Keep flying speed: fly fast!

SUGGESTIONS FOR READING ON CLIMBING AND GLIDING TURNS

Swoffer, Frank A., *Learning to Fly*, chap. XII. Pitman.
Jones, Byron Q., *Practical Flying*, chaps. XXVIII, XXX. Ronald.
Studley, Barrett, *Practical Flight Training*, chap. XVI. Macmillan.

Questions for Review

1. Discuss the principles underlying climbing and gliding turns.
2. Of what value is the climbing turn, when you are taking off?
3. Explain the technique of making a climbing turn.
4. What dangers surround the climbing turn? How may they be avoided?
5. Interview a pilot of long standing as to the *chandelle*, its purposes and execution.
6. To what purpose is the gliding turn most commonly put?
7. How does the operation of making a gliding turn differ from a straight glide?
8. What are the dangers in making a spiral? How should one avoid them?
9. Describe the use of the S-turn.
10. Give three rules regarding climbing and gliding turns.



CHAPTER XVI

STALLS AND SPINS

A STALL is the condition resulting from loss of flying speed. It is evidenced by the diminishing responsiveness of the controls, especially the ailerons. A spin is the rotation about an axis almost perpendicular to the earth, of a stalled plane which is falling, nose downward. Practice in stalls and spins is essential during the last hours of dual instruction, so that you will be able to recognize and to correct any accidental stalls and spins which may occur when you are soloing. Stalls and spins are the causes of the majority of crashes.

A plane is stalled when it has insufficient flying speed to maintain horizontal flight. (See Figure 134.) Its lifting power then becomes less than its weight, the consequence being that it falls. Since the nose of the plane is by far the heaviest part of it, a plane always falls nose first, as an arrow does, although it may start to drop while still in a horizontal position, or even tail first. But the nose soon points downward and, unless the recovery is effected, the plane dives or spins towards the earth.

The Danger of Stalls. The danger of a stall is in lack of sufficient altitude to effect recovery. The student can tell how much altitude is necessary only after he has tried stalls a number of times. If the plane is near the ground there is little space for recovery, and the plane crashes. Unfortunately, pilots often stall planes unintentionally when they are near the ground. They become so occupied in trying to make a "graveyard" glide, or in making a turn when close to the ground, that they lose too much speed and the plane falls before they can make a recovery. When they are well up in the air, on the other hand, they receive warning of a stall in time to check it, or at least they have enough altitude in which to make a safe recovery.

Most accidents in aviation are due to stalls. Stalls, if they are

not checked, result in spins, at least, in most planes. This is not a real danger, however, since the stall can always be stopped before the spins start, if there is sufficient altitude.

Causes of Stalls. A number of conditions may bring about a stall, the most important of them being the following:

1. *Skidding.* A skid always makes the plane lose speed. If the skid is a bad one, the plane may not only stall but it may go

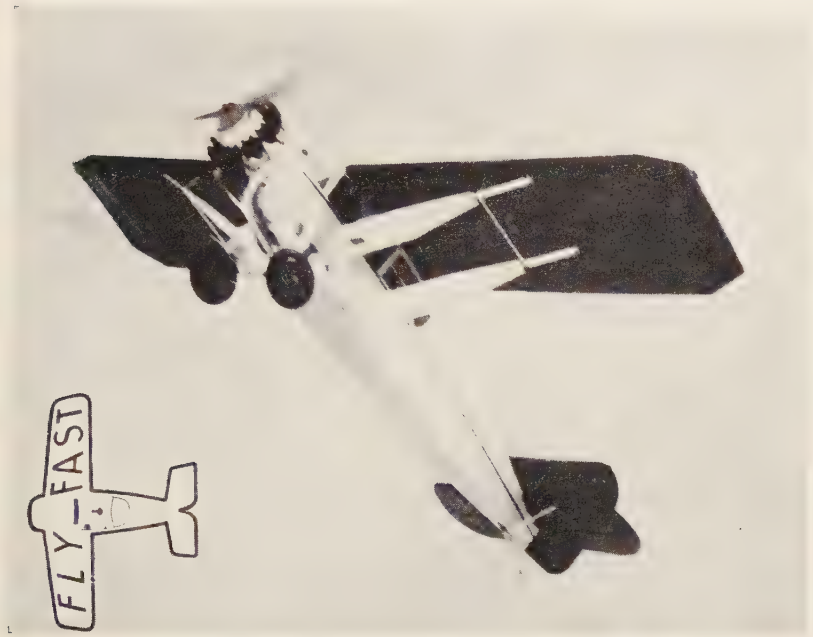


FIG. 134. A PLANE IN STALLED POSITION

This Bellanca plane was put into a climb so steep that it lost flying speed, and stalled. A stall may readily occur in a climb, with throttle open, or in a flat glide, with throttle closed.

into a spin. It is often hard for the beginner to recognize a stall due to skidding, since the nose of the plane may be level with or even below the horizon while at the same time the angle of bank has not been sufficient. The easiest way to recognize a stall is by the manner in which the controls handle. If they move too easily, that is, if they are "soft," it is a sign that the plane has not enough

flying speed. When the plane is flying swiftly there is little danger of this because the slightest movement of the controls is immediately reflected in the path of flight.

2. *Stall Occurring in Level Flight.* As just described, a pilot may put his plane into a stall in level flight by reducing the speed of the plane through a skid. If he has enough altitude this is not dangerous because he can dive enough to regain his speed and thus bring the plane under control again.

3. *Climbing.* If a plane is made to climb too steeply it will stall. (See Figure 135.) This is perhaps more dangerous than a stall during level flight, but the plane may be brought under control in the same manner, by diving. The stall comes more quickly, however, and requires quicker action on the part of the pilot.

4. *Climbing Turn.* One of the most dangerous types of stalls is that occurring when a plane does a climbing turn at too steep an angle of attack. If the rudder is not immediately reversed, the stall will result in a tail spin. It is quite difficult to recognize the impending stall in a turn.

5. *Glide.* A stall is certain to occur if the pilot tries to stretch out his landing glide too far.

6. *Gliding Turn.* As in a straight glide the plane will stall if the glide is too flat; there is also the additional danger of skidding. If you turn too sharply you are apt to stall, too, the stall resulting immediately in a tail spin.

There are several types of stalls which come under the heading of acrobatics, and which are treated in a subsequent chapter.

Recovering from Stalls. Stalls are invariably remedied by regaining speed. This is done by diving. The only thing necessary to keep the plane from stalling is speed. A stalled plane must drop, and it is during this descent that it regains the speed necessary to maintain it in level flight. The faster and the farther a plane falls, the more speed is obtained and the more fully control is restored, provided, of course, that the plane is diving, and not spinning.

If the wings can be kept level, that is, if it is not spinning, most planes will restore control through this fall. However, the safest thing to do is to restore it more quickly through diving

Curtiss Flying Service, Inc.

FIG. 135. A STALL RESULTS FROM TOO STEEP A CLIMB

Nothing is gained by keeping the stick too far back in the climb. The engine will labor and flying speed will be lost. In the above picture, the climbing angle is perhaps too steep for the relatively small (90 horse-power) engine used.

voluntarily, and, if it shows a tendency to fall to one side or the other, correct this with the controls.

When the ship is stalled in level flight, recovery may be effected by a mere quick forward motion of the stick. (See Figure 136.) This puts the plane into a glide, during which the throttle may be opened wider, so that little altitude is lost. If the plane stalls during a straight climb, the same remedy is effectual, if done in time. If, however, the plane is stalled completely, it will be necessary to dive. The symptoms of a complete stall are these: the plane's nose is well up on the horizon; it will stay in this

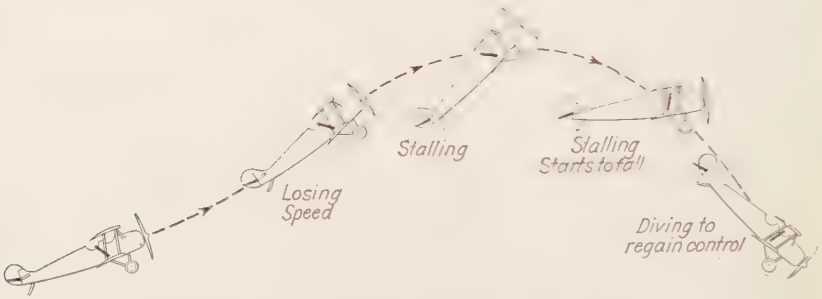


FIG. 136. ENTERING AND RECOVERING FROM A STALL

This maneuver is perhaps the most important of all for the student to master. To recover from a stall, push the stick forward, and regain flying speed.

attitude for a few seconds as the plane begins to drop; the plane may even slide back a little. Then, the nose will tip down and the plane will lunge forward. The quicker the nose is brought down by forward motion of the stick, the sooner control may be recovered. In any simple stall, the remedy is merely to push the stick straight forward.

If the stall occurs when the plane is turning due to skidding, opposite rudder and ailerons, with forward stick, should be applied at once. These must be used as soon as it is evident the controls are soft, or "going out." Both rudder and aileron are needed to check a skid stall. You must level your wings as soon as possible, and push the stick downward for recovery. Above all, reverse your rudder at once to avoid a spin.

In recovering from a stall by diving, do not pull the ship out of the dive before it has picked up enough speed to give you adequate control. Nor should you pull it out of the dive too suddenly, because this at once changes the angle of attack from low to high. The result may be so violent that the weight of the plane will be greater than the lift; so that another stall will ensue, if not a crash to the ground.

Instruction in Stalls. Although they are disconcerting to a nervous student, stalls should be practiced early in flight training. The stall is the critical maneuver in flying. It is the characteristic of flight which differentiates it from any other form of locomotion. It is the quintessence of airplane behavior. A complete knowledge of stalling and its results, consisting not only of a mastery of the theory, but also of actual experience, is perhaps the most important requisite of flying technique.

The stall, terrifying as it is to some people, and dangerous as it always is when not under control, is, none the less, a phenomenon without which flying, as we know it, would not be possible. A landing is really nothing but a stall which takes place at the end of a glide. In fact, a landing would be impossible without stalling the plane.

For these reasons, you should learn stalls from the outset. You may learn a great deal about landing a plane by landing it in the air, so to speak. Climbing stalls, too, give you the best of practice, and once you can do them without nervousness, and with complete command, you have made real progress.

To avoid danger, you must climb at least 1,000 feet before practicing stalls. Some careful instructors insist on twice this altitude. The instructor will then close the throttle a little so that the plane will stall easily. He will hold the stick back until the plane approaches the stalling point, then bring the nose down. This allows you to mark the position of the nose above the horizon and to hear the engine labor. The second time he raises the nose, he will hold it up. As flying speed decreases, he will have to pull the stick farther and farther back in order to maintain the height of the nose above the horizon. Right rudder must be applied, otherwise the ship will turn slowly to the left, due to engine torque. If the stick is moved from side to side, you will see that

the ailerons have no effect. At last, the power of the engine is insufficient and the nose will drop of its own accord. As it drops it may start to turn to one side or the other. In order to regain control, the instructor will push the stick forward as the nose drops and, if necessary, correct the turn with the rudder. When the ship gains speed from the dive, he will pull the stick gradually back.

Then he will ask you to repeat the whole process of going into a stall and recovering flying speed. When you have tried this several times with the motor running at low speed, you will effect a stall with power off by closing the throttle entirely as soon as the plane stalls. The procedure with throttled motor is the same as when the engine is running, except that the downward lunge is more violent.

A stall can, of course, be checked before it so increases that the nose falls of its own accord. Whenever an accidental stall occurs, push the stick forward as soon as you notice that the engine labors and that the ailerons begin to be unresponsive. The sooner you push the stick ahead, the shorter will the resulting dive need to be.

You cannot give too much attention to these maneuvers. Remember that he who is master of the stall is master of his ship.

Spins. In a straight stall, the plane drops nose first, and directly forward. But this is not what usually happens. At the height of the stall, the ship is standing on its tail, in mid-air, so to speak, and is in a state of equilibrium. Now, as it begins to drop, it does not usually plunge straight forward and downward, but one wing falls before the other. In other words, the ship falls off to one side, at the same time that it begins to fall forward. This is the beginning of a spin.

In a spin, the tail whirls in corkscrew fashion around the nose. (See Figure 137.) In the spin, the ship keeps skidding as it falls, so that flying speed is not sufficient to make the controls operative. When in a spin, the ship will continue indefinitely diving and skidding, as long as the elevators are in the upward position.

The causes of spins are the same as the causes of stalls. If the plane is already banked when it stalls, however, the spin

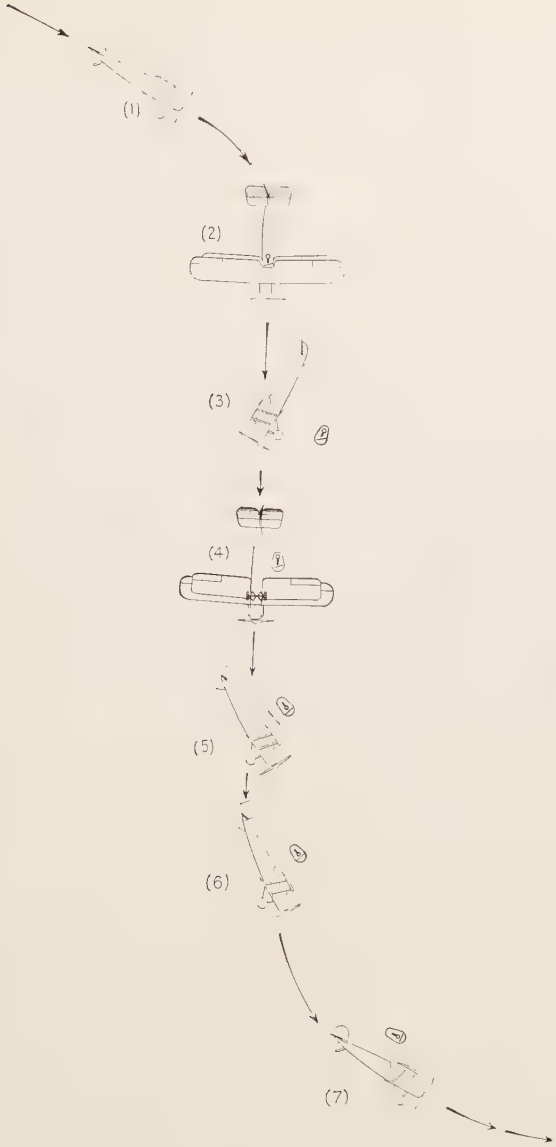


Fig. 137. Entering and Recovering From a Spin

(1), (2), (3) and (4) show the plane in a spin; (5) and (6) show the correct position in which to hold the stick in order to bring the plane out of the dive.

results immediately, and there is no intermediate falling of the nose. The most common causes of such immediate spins are: first, a skid; second, too steep a climbing turn; and third, too flat a gliding turn.

Instruction in Spins. Your instructor will probably show you something about spins in the eighth or ninth hour of dual instruction. Prepare for an experience that will be somewhat unpleasant. But the sensation of spinning is one with which you must become familiar. Spinning will bring out any tendency to nausea you may have, although, much as with seasickness, after you have become accustomed to the motion of the plane this will disappear. Incidentally, it is a comfort to have your safety belt fairly tight, when spinning.

When the plane is spinning, action must be taken immediately and positively in order to effect recovery. There are four corrections possible. First, push the stick forward to neutral; second, apply up aileron; third, apply up rudder; fourth, throttle the engine.

It is exceedingly difficult to recover from a spin when the plane is under power. Besides, the excessive speed puts the ship under undue stress. The rudder and aileron movements stop the ship from spinning. The elevators throw the plane into a dive. It is imperative that the elevators be used correctly. If the stick is held back, the spin will continue. If it is pushed forward too far and held there, it will force the plane into a very steep dive and some ships will even turn over on their backs. (See Figure 138.) To recover *quickly* from a spin, however, it is necessary to push forward (beyond neutral) on the stick, at least momentarily. Whether up aileron and opposite rudder should be applied depends on circumstances.

The above procedure may not be necessary or desirable in all ships. In some, merely to neutralize the controls is all that is required. The tendency today is to design planes so that they will of themselves recover from spins. In all ships, however, over-control should be avoided and it is fairly safe to say, neutralize all controls as soon as possible. The ship will then be in a straight glide.

As soon as the ship is in the dive, hold the stick in neutral a

second to gain speed, then pull it back gradually. If you pull it back too suddenly, a stall will be caused with another spin as the eventual result. (See Figure 138.) When you are recovering from

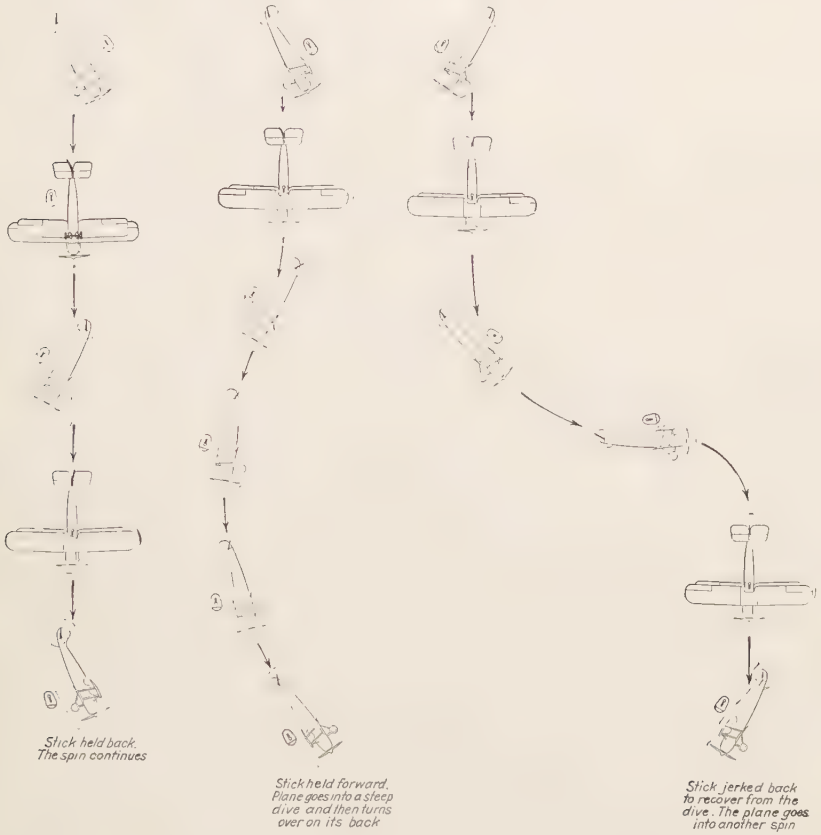

Stick held back. The spin continues
Stick held forward. Plane goes into a steep dive and then turns over on its back
Stick jerked back to recover from the dive. The plane goes into another spin

FIG. 138. INCORRECT USE OF THE STICK IN A SPIN

The *correct* use of the stick is to ease it forward until the spinning stops, and then to pull back gently and pull out of the dive.

a spin, move the controls promptly but gently. Any jerkiness will be loss of effort and may strain the ship.

It is important to know how to spin in order to accustom one's self to the sensation and in order to know how to recover from the spin. If the pilot should go into an involuntary spin without

knowing how to correct it, the result would probably be a crash. (See Figure 139.) An experienced pilot can pull out of a spin safely when he is as close to the earth as 200 feet, but a beginner needs much more altitude if he is to perform the maneuver with safety. A spin should never be practiced under 2,000 feet. When the rudder and stick are pushed over hard to start it, the spin is

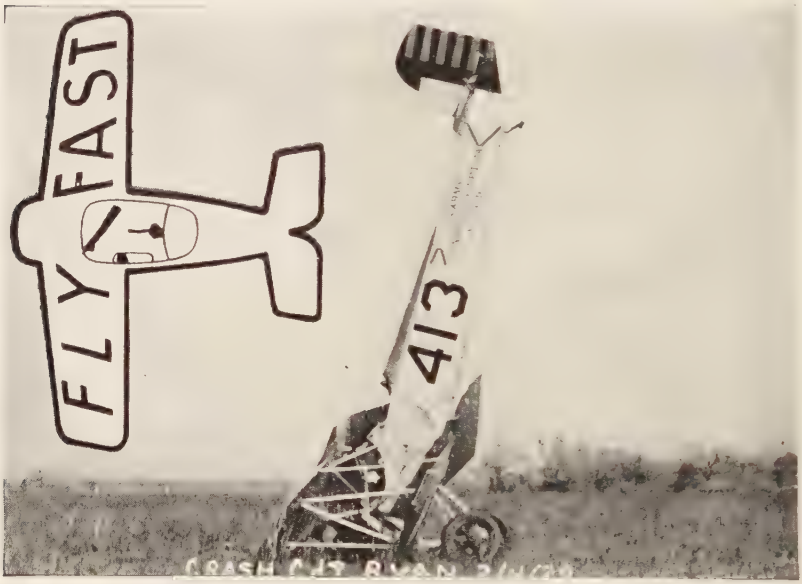


FIG. 139. THE END OF A PERFECT SPIN

To many students, practice in spins is unpleasant. But recovery from them ought to be practiced constantly. The knack of recovery is not difficult. But not to know it may mean something like this.

very rapid. The rate of descent varies with the degree to which rudder and stick are used.

Skilled stunting pilots can recover from spins without going through the diving process, but to do so subjects the plane to severe strain for which the average plane is not designed. Rudder, elevator, and ailerons are all needed in the process. The rudder is used to bring the nose up, the stick is pushed forward so that the elevators bring the plane out of the turn, and the ailerons are moved in the proper direction to level off the wings. This opera-

tion involves reverse-control flying, which is treated in Chapter XVIII.

The slotted wing device, discussed in Chapter V, is a means of eliminating the danger of spins. The slots allow a smooth flow of air over the wing surfaces, even when the plane is in a stalled position, so that the ailerons are effective, and the falling off of the plane is automatically prevented.

Five Things to Remember about Stalls and Spins:

1. Move the controls promptly but gently.
2. To check a stall, push the stick forward.
3. To stop a spin, use:
   a. Elevators neutral
   b. Up aileron
   c. Opposite rudder
   d. Throttle closed
4. Avoid involuntary stalls and spins.
5. Keep flying speed: fly fast!

SUGGESTIONS FOR READING ON STALLS AND SPINS

Jones, Byron Q., *Practical Flying,* chap. XXXIV. Ronald.
Clevenger, C. P., *Modern Flight,* chaps. VI, VII. Alexander.
Swoffer, Frank A., *Learning to Fly,* chap. X. Pitman.
Warner, Edward P., *Airplane Design Aerodynamics,* chap. XXV. McGraw-Hill.

Questions for Review

1. Obtain the opinion of an experienced pilot as to the statement that "the stall is the most important single subject in flight training."
2. Classify the causes of stalls.
3. What are the methods to be used in recovering from stalls?
4. What is meant by "landing a plane in the air"?
5. What are the methods used for practicing stalls?
6. What is a spin? Show by diagrams.
7. What causes a spin?
8. Interview two pilots as to the methods of coming out of a spin.
9. Why should the throttle be closed in pulling out of a spin?
10. What is the practical value of slotted wings? Obtain your information from someone who has used them.

CHAPTER XVII

SOLOING

To SOLO is to fly alone. You will begin to solo after 10 or 15 hours of dual instruction. Beginning at the time of your first solo, the majority of your training flights will be made alone.

Before you will be allowed to solo, you must be able to handle the plane safely; that is, you must be able to taxy, take off, climb, glide, make turns, approach, and land, without losing control of the plane. You must be familiar with the behavior of the ship when it is in a stall, and with the method of regaining control.

Whether or not you fulfil these conditions is a matter for the instructor's decision. Although the dual instruction course is normally of 10 hours' duration, it is frequently necessary to extend it by from 3 to 5 hours. The instructor will not allow you to solo until you have shown ability to handle the plane with safety, nor until you have become sufficiently accustomed to the air to be self-possessed during a flight.

Purposes of Soloing. When you have begun to solo, do not think that your instruction has ceased. The instructor will watch all your early solo flights from the ground, so that he may, when you land, correct the mistakes you have made. The first 10 hours of soloing are interspersed with periods of dual instruction. Even after you have acquired a license, you will not learn advanced maneuvers by experimentation alone; you will be taught all new feats by dual instruction, before you attempt them in a solo flight.

Although dual instruction teaches you to perform maneuvers correctly and with safety, the presence of the instructor-pilot at the controls allows you to rely upon him to make all decisions. But when you solo you are forced to exercise your own judgment. The actual maneuvering of the plane now seems comparatively simple to you. It is the ability to calculate how landings should

be made under varying conditions, how to take effective action in emergencies, and how to make countless other quick decisions, which is difficult to acquire. The acquisition of this ability can be stimulated only by the responsibility incurred by having the plane completely under your own control.

Solo flying gives you practice, as well as exercising your judgment. Practice enhances accuracy in those maneuvers which you are already able to make with safety. Constant repetition of operations begins to make them instinctive.

Conditions for Soloing. Until you have had considerable experience, you should solo only under propitious conditions. The weather must be as favorable as possible. A low wind (if any wind at all), no rain, and a high ceiling are essential. Rough weather conditions make the handling of the plane difficult, and would be apt to lessen your confidence. Most instructors do not tell you beforehand when you will make your first solo, on the theory that anticipation would make you nervous and decrease your faith in your own ability.

The First Solo. When the instructor considers you prepared to solo, it is customary for him to take you up as usual, and put you through the whole gamut of maneuvers with which you are already acquainted. Meanwhile he will give you any necessary warnings. When you have landed, the instructor will get out of the plane, remove any cushions, and perhaps the stick, from the front cockpit, and direct you to take the plane up alone and make a circuit of the field. Be sure you know exactly what he wishes you to do before you take off. When you are in the air, perform these maneuvers directly, without wasting any time in wandering about. Then land. The first solo should not last much longer than 10 minutes, so that the tax on your nerves is not too prolonged.

You will find the first solo to be an affair of moment. The instructor's head no longer projects from the cockpit in front of you, nor do you feel his correcting movements of the rudder-bar and stick. You may, however, be able to handle the controls with less tenseness when the instructor's scrutiny is thus removed. But do not allow yourself to be overconfident, for this might cause you to be slipshod. Use, in your movements, all the care

and precision which you practiced when you were less used to flying. Concentrate to the fullest extent of your ability. Be sure that you have gained sufficient altitude before you start to make any turns. You will notice that the plane climbs more rapidly with the instructor's weight removed.

The emotions of various instructors during a pupil's first solo are interesting. One pilot was heard to remark, as he watched the student in the air, "He knows what do do. The question is, will he do it?" It is a nervous moment for the instructor. There would be advantages in being able to talk from the ground to the student who is soloing. (See Figure 140.)

When you reach the ground after your first solo, the instructor will criticize you upon any points that need improving. Keep these suggestions in mind, that you may apply them in later flights.

Ensuing Solo Flights. The Department of Commerce requires at least 10 hours of solo flying for a private license. During all 10 hours he is supposed to be in full command of the ship.

The 10 hours should, if the weather permits, be taken within a fairly brief period; but at least 10 days should normally be allowed. The longer the lapse of time between the flights, the more you lose the "feel" of the controls which you have begun to acquire. Early solo flights should be of not over an hour's duration. This length of time is sufficient to allow numerous repetitions of each maneuver, without taxing your nerves severely. Some time during this period will be spent in dual instruction, for the purposes of demonstrating the means of correcting your faults, giving you advanced training in such maneuvers as spirals and spins, and allowing the instructor to check up on the progress you have been making.

The course of instruction for early solo flights depends entirely upon the instructor. Before each solo he will assign to you certain operations which you are to practice. You must attempt no maneuver without his permission. Usually the first 5 hours are spent in take-offs, turns, and landings, until you have gained such competence and self-confidence that there is no danger of your loss of control. The other 5 hours are then devoted to the acquisi-

Boeing Air Transport System

FIG. 140. CAN THIS IDEA BE USED FOR INSTRUCTING THE SOLO STUDENT?

In many ways it would be desirable for the instructor to converse with the student, and this could be arranged by a system like this two-way radio, although the idea of it is to communicate with pilots who are flying transport routes.

tion of greater accuracy in landings, and to the practice of spirals and stalls.

* * * * * * * * *

When you have received your private license, the subsequent solo flights should be frequent enough so that you will not lose the "feel" of the controls, which you have now begun to acquire. Advanced instruction will be given in such things as precision landings, cross-country flying, and acrobatics.

Five Things to Remember about Soloing:

1. Concentrate your whole attention on each move you make.

2. Your flight is not complete until the plane comes to a full stop after the landing.

3. Ask your instructor about any occurrence during the flight which you did not understand.

4. Make no experiments; do only those maneuvers which you have already been taught.

5. Keep flying speed: fly fast!

SUGGESTIONS FOR READING ON SOLOING

Swoffer, Frank A., *Learning to Fly*, chap. IX. Pitman.
Jones, Byron Q., *Practical Flying*, chap. XXXI. Ronald.
Studley, Barrett, *How to Fly*, chap. XV. Macmillan.

Questions for Review

1. What experience should the student have before solo?
2. How many hours' solo are required for a private license? Must this time be entirely solo, or is time spent in dual instruction counted?
3. What benefits are to be derived from solo flying?
4. What conditions are propitious for early solo flying?
5. What preparations are made by the instructor, preparatory to his student's first solo?
6. What rules should you bear in mind while making your first solo?
7. Interview a pilot as to his feelings when one of his students makes his first solo.
8. What would be the advantages and disadvantages of a means of communicating from the ground with a solo student?
9. Ask an instructor how he knows from the ground what the student is doing.
10. Interview three students as to what benefits they derived from their early solo flights.

CHAPTER XVIII

REVERSE-CONTROL FLYING AND ACROBATICS

The principles of reverse-control flying are involved whenever the plane makes a turn which requires a bank of 45 degrees or more. Reverse-control turns should not be attempted until the student has flown at least 20 hours, since they are both difficult and dangerous: difficult in that the stick and rudder-bar are not employed in the usual manner, and dangerous in that stalls are frequently occasioned by the loss of speed due to the sharp bank. Nevertheless, the principles of reverse-control turns are involved in most air stunts and must be learned before any acrobatics are attempted.

Acrobatics in the air are not necessarily reckless or useless feats. A knowledge of acrobatics has a twofold purpose: first, it frequently enables the pilot to recover from awkward positions into which sudden bursts of wind, in a storm or over mountainous country, are apt to throw the plane; and secondly, the use of some acrobatics is often of aid in performing such maneuvers as forced or spot landings. In military flying, a knowledge of acrobatics is, of course, essential.

Not only are acrobatics useful, but also they are safe, if performed at sufficient altitude. It is true that there is loss of speed during parts of most stunt flying, so that stalls are likely to occur. But if the same care and precaution are taken in the performance of acrobatics as in normal flying, there will be but little more danger in the one than in the other. There is an endless variety of stunts which may be performed. Only the simpler and most useful ones will be treated here.

Elements of Reverse-Control Flying. Reverse-control flying actually means that, when a bank of 90 degrees is made, the elevators have the same effect in controlling the plane in relation

to the horizon that the rudder had in straight flight, and that the rudder has the same effect that the elevators had in straight flight. In other words, when a 90-degree bank is made, the functions of the elevators and the rudder are reversed. The elevators still control the longitudinal, and the rudder the directional, stability of the plane in relation to its own axes. But, in changing from straight flight to a 90-degree turn, the ship has moved from a horizontal to a vertical plane.

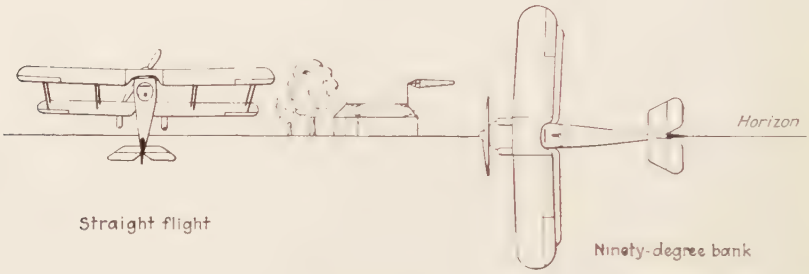


FIG. 141. THE EFFECT OF RUDDER AND ELEVATORS IN A REVERSE CONTROL TURN

In Straight Flight. The rudder is at right angles to the horizon and governs the turning of the nose around the horizon. The elevators are parallel to the horizontal and raise the nose above or drop it below the horizon.

In a 90-degree Bank. The rudder is parallel to the horizon and acts to raise the nose above or drop it below the sky line. The elevators are at right angles to the horizontal and act to turn the nose around the horizon.

This will be more easily understood, if the student considers that the positions of the elevators and the rudder in relation to the horizon change places when the plane goes from straight flight into a 90-degree turn. (See Figure 141.) In straight flight, the axis about which the elevators turn is parallel with the horizon, so that a movement of them lifts the nose above or drops it below the sky line. When the bank is so steep that the wings form a 90-degree angle with the plane of the horizon, the axis of the elevators is also at right angles to it, and they act to turn the nose around the horizon. Similarly, the rudder turns the plane around the horizon in straight flight, but lifts or raises the nose in relation to the horizon in a vertical bank.

How to Make a Reverse-Control Turn. To make a 90-degree right turn, apply right aileron and right rudder as usual. (See Figure 142.) When the angle of the wings to the horizon approaches 45 degrees, further pressure on the rudder-bar will be less effective in making the turn tighter. On the contrary, as the rudder is turned farther to the right, in a steep right turn, it will begin to have the effect normally resulting from lowered elevators, and the nose will tend to fall below the horizon. Now, if, in order to counteract this, and to raise the nose again, you were to pull back on the stick, you would notice that the raised elevators, instead of having the desired effect, would act to tighten the turn. Therefore, as the bank begins to pass the 45-degree angle, the original right rudder and neutral elevators, which were used to start the turn, must be gradually changed to raised elevators and relaxed rudder. When the wings are finally perpendicular to the horizon, the rudder-bar should be neutral and the elevators away up. Unless the stick is hard back, so that the turn is tight, the plane will sideslip.

To come out of the right reverse-control turn, apply left aileron, and gradually neutralize the elevators. Do not exert any pressure on the rudder at this point to stop the turn; this would result in a bad sideslip. When the bank again approaches 45 degrees, however, and the elevators and rudder begin to reassume their normal functions, left rudder should be gradually applied, and the elevators left in neutral.

When the angle of the wings to the horizon is exactly 90 degrees, the only operative control is the elevators. Until a vertical bank is reached, however, the ailerons are of great importance in a reverse-control turn. Although their function (unlike the other controls) is not reversed by the steep bank, they must be used with a good deal of precision. Once 45 degrees is past and real reverse-control is needed, up aileron must be applied in order to keep the plane from rolling too far.

True 90-degree turns are rarely made. Only high-powered engines are able to sustain flying speed when the wings are exactly perpendicular to the earth's surface.

Recovery from Maneuvers. In an up-to-date ship, in order to recover from any maneuver in which the plane is in a position

The Fairey Aviation Company, Ltd.

FIG. 142. A VERTICAL BANK

In this exactly vertical position, the rudder is held vertical, and the stick way back. The raised elevators keep the ship revolving, much as the rudder does in a normal turn.

other than a level one, there is one formula which is always effective: centralize the controls. There are control movements peculiar to each maneuver which will effect the quickest recovery. But if you get into some position from which you do not know the method of recovery, centralize the controls, and the plane will eventually right itself.

The practice of a few simple stunts will increase your confidence and accustom you to sitting in a plane which is at any angle to the horizontal.

Sideslip. The sideslip is a simple and useful maneuver. This feat is nothing more nor less than the error against which you were warned when first making turns, but now put to good use. To sideslip, the plane is banked downward, preferably into the wind, and up rudder applied. The bank, without its corresponding turn, causes the plane to slip downward in the direction of the lowered wing. Even though the engine be kept running throughout the maneuver, the nose should be held below the horizon, in order that forward speed may be maintained. When slips are made with throttled engine, the longitudinal axis of the plane must be at a sharper angle with the horizontal than when in the normal angle of the glide.

To recover from a sideslip, push the stick toward the raised wing, centralize the rudder-bar, and flatten out. Do not continue the slip too long.

Loop. The loop is usually one of the first stunts which the student is taught. It is a complete circle made in a vertical plane. (See Figure 143.) Since an excess of speed is required to start a loop, the plane is put into a glide with the throttle wide open. When the air-speed indicator shows sufficient increase of speed, pull the stick back gradually. A jerk on the stick will cause the plane to stall; but too slow a pull on the stick will waste the needed impetus before the top of the loop is reached. Therefore, you must follow the instructor's directions exactly. Pull the stick away back as the vertical position of the plane is reached (see Figure 144) and hold it there until the ship is inverted at the top of the circle. Then close the throttle and ease the stick gradually forward. A dive will be incurred by the speed acquired in the descent

from the top of the loop. Pull the plane out of the dive gently, and when it is level, open the throttle and resume normal flight.

Great care must be taken throughout the loop to retain lateral balance. (See Figure 145.) This is done by keeping watch of the horizon at the end of either wing. Remember that, when the plane is in an inverted position, the ailerons have the reverse of their ordinary effect. For example, if the right wing drops at the top of the loop, push the stick to the right, instead of to the left. This, however, is the instinctive thing to do.

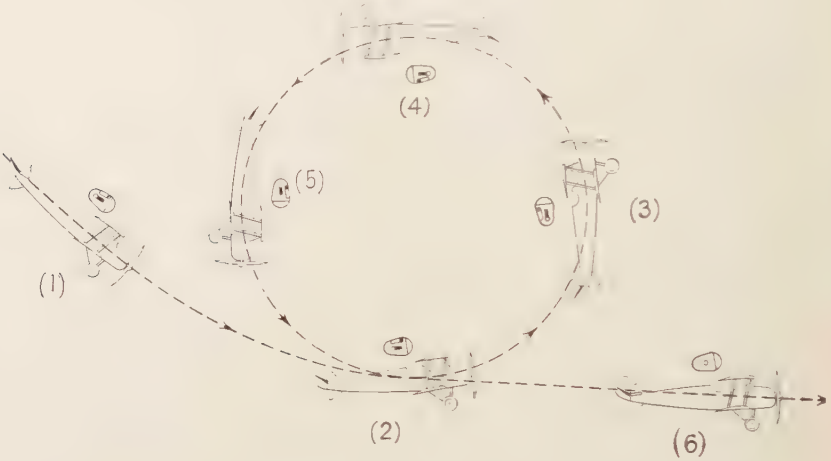


Fig. 143. A Loop

Unless the plane has an excess of power, it is dived in order to gain speed before entering the loop. Near the top of the loop, the throttle is closed, and remains closed till the ship levels off.

Split-S Turns and Wingovers. The split-S and the wingover are both abrupt 180-degree turns produced by means of a steep bank. The split-S turn, however, is effected with the plane in a stall, so that considerable altitude is lost, while the wingover is executed with flying speed throughout the maneuver. To enter a split-S turn, keep the engine running at normal speed, and pull the stick back in order to produce a stall. Then apply hard rudder in the intended direction of the turn. The plane will fall into a diving turn. To recover, use up aileron, neutral rudder, and stick back.

FIG. 144. ASCENDING PHASES OF THE LOOP

The ship is in a vertical position, as it climbs to the top of the loop. Stick is held back and throttle is wide open.

The execution of a wingover is similar to that of a split-S, except that the wingover is entered by means of a climbing turn which becomes steep so gradually that flying speed is maintained.

Fig. 145. Descending Phase of the Loop

The throttle is closed and the ship descends in a dive, and then is gradually pulled out. It is important to keep the wings level. To do this, make use of the ailerons, as the pilot is doing in this picture. This extreme use of the ailerons is necessary because of the torque.

When the plane approaches a stall it is immediately put into a gliding turn in the same direction by pressure on the lower side of the rudder-bar. The sharper the bank used, the tighter the turn will be. Slips and skids must be avoided. To recover, use

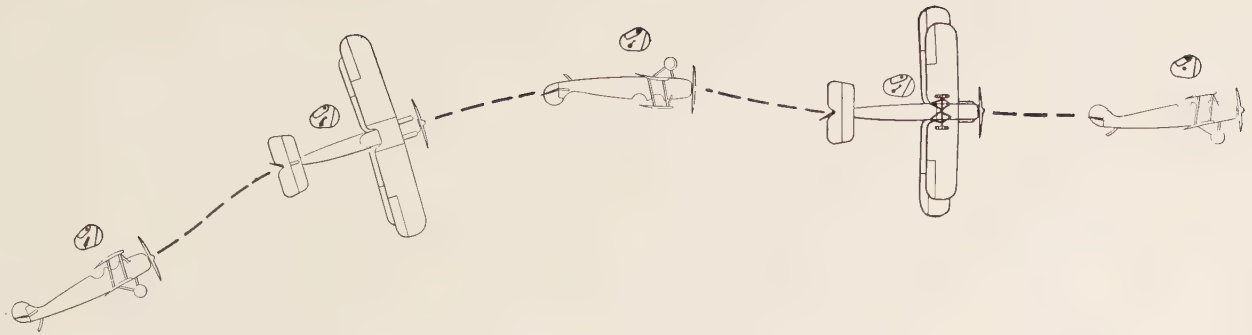


Fig. 146. The Roll

The roll, or barrel roll, is a more difficult feat than the loop. The plane describes a horizontal corkscrew motion through the air. The throttle is kept open throughout the maneuver.

the same control movements as in recovery from a reverse-control turn, with sufficient elevators to bring the nose up on to the horizon.

Rolls. The roll is a maneuver in which the plane, while flying approximately straight, makes a complete revolution on its longi-

Fig. 147. A Roll

Unlike the loop, the roll requires the use of all the controls, accurately coördinated. Although important in most acrobatic flying, the roll requires much skill. (Note that the position of the ailerons does not agree with the control diagram.)

tudinal axis. (See Figure 146.) It is a comparatively difficult feat. It is performed while the engine is running, by holding the stick away back and applying hard aileron and rudder in the direction of the roll. Hold all these controls full on, until the plane nears its normal position, then centralize them. Figure 147 shows a roll.

Immelmann. The Immelmann, or Immelmann turn, is a half-loop, followed by a half-roll, so that the plane is right side up and flying horizontally at the end of the maneuver. This reverses the direction of flight and at the same time gains altitude, always provided the plane has sufficient power to execute the maneuver.

FIG. 148. INVERTED FLIGHT

The skilful pilot is able to perform many maneuvers while flying "on his back." This position is entered by means of a half loop or a half roll.

Upside-down Flying. Upside-down flying consists of maneuvering the plane when it is inverted. (See Figure 148.) In this position the pilot at first feels some discomfort and also discovers that the stick controls are reversed, or apparently crossed, for a right turn necessitates left stick and right rudder. Level flight requires forward pressure on the stick.

Inverted flight may be begun by a half-roll or by a half-loop. An inverted glide must be much steeper than a normal glide due to the inefficiency of the wings when inverted.

Falling Leaf. The falling leaf is a feat in which the plane is stalled and allowed to fall off to one side, brought back to level flight, stalled again, and allowed to fall off to the other side, and so on in a long series. To execute a falling leaf, the throttle is closed and the stick held back. These controls remain so positioned throughout the maneuver. As soon as the plane stalls, it will fall off to one side. Apply opposite rudder immediately. When the plane has fallen far enough to gain a little speed, it will level itself laterally and, since the elevators force the plane to climb, another stall will result. This time the rudder must be used to assist the plane to fall off in the other direction. By pressure on the high side of the rudder, the plane will again level off. This process may be repeated as many times as you wish, as long as you have sufficient altitude.

Formation Flying. Some practice in formation flying, if it is given you, will increase the accuracy with which you manipulate the controls. When two or more planes fly together, they fly in formation, as birds do, in such a manner that the group will not be separated, while the danger of collision will be removed.

The simplest formation consists of three planes arranged to form a letter V, with a leader and two following planes. (See Figure 149.) The leader sets the pace and direction for the group. It is his duty to fly slowly enough so that the following planes will not be left behind, and fast enough so that they will not be obliged to creep ahead of their positions in order to maintain flying speed.

The following planes usually fly about 100 feet behind and at a slightly greater altitude than the leader. The task of the pilots of the following planes is, in theory, an easy one; it requires a good deal of practice, however, to regulate the speed, to increase the ship's velocity when flying on the outside of a curve, or to decrease it on the inside of a curve, so as to keep in the formation. Formation flying is important in military evolutions. (See Figure 150.)

* * * * * * * * *

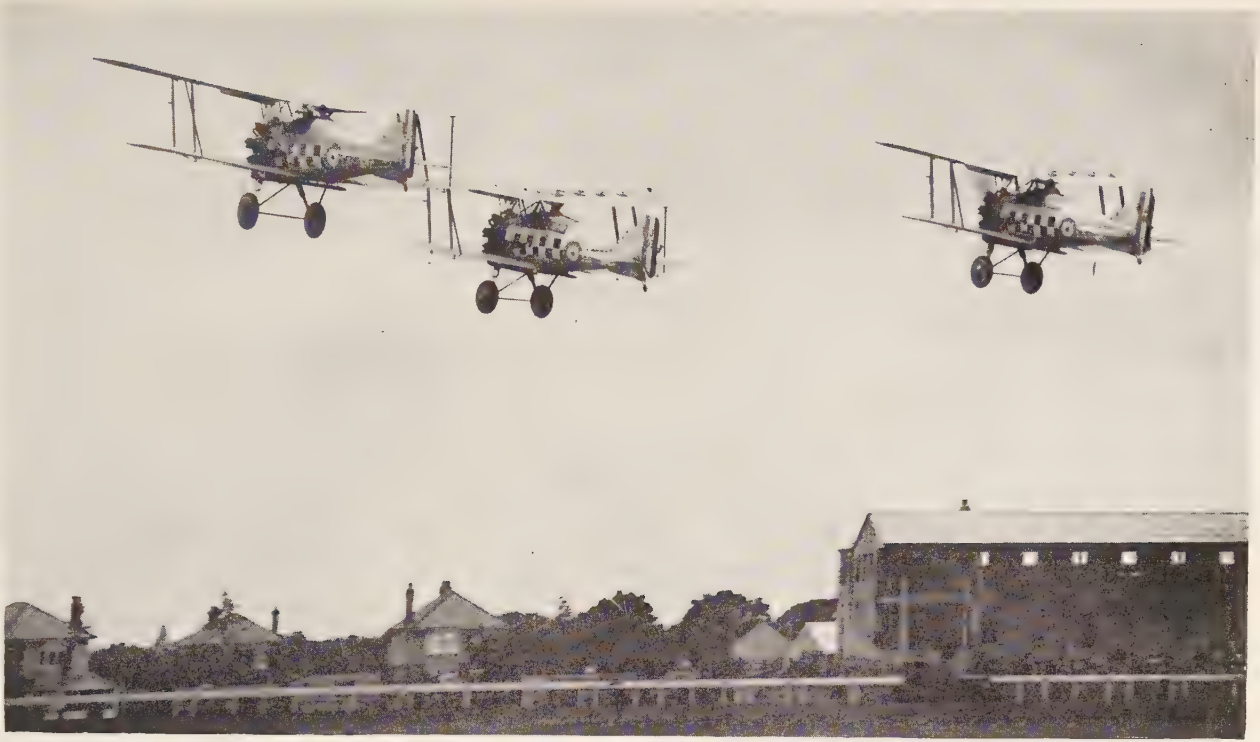


FIG. 149. ELEMENTARY FORMATION FLYING *Flight*

Notice that the following planes fly at a slightly higher altitude than the leader. This enables their pilots to see better. Three Gloster "Gamecocks" taking off.

Familiarity with difficult maneuvers adds a great deal to a pilot's proficiency. When you have performed various acrobatics, you will probably feel at ease when the plane is in any position, and you will be able to act coolly and wisely in any vicissitude.

Five Things to Remember about Reverse-Control Flying:

1. Do no stunt flying except at high altitudes.
2. Check your altitude after you come out of each maneuver.
3. Imagine, in doing reverse-control flying, that you are in a normal position, and that the rest of the world is out of level.
4. If you do not know how to recover from stunt, neutralize your controls. Easing the stick forward may help.
5. Keep flying speed: fly fast!

SUGGESTIONS FOR READING ON REVERSE-CONTROL FLYING AND ACROBATICS

Studley, Barrett, *Practical Flight Training*, chap. XXII. Macmillan.

Clevenger, C. P., *Modern Flight*, chap. XII. Alexander.

Swoffer, Frank A., *Learning to Fly*, chaps. XII, XIII. Pitman.

Chatfield and Taylor, *The Airplane and Its Engine*, chap. XI. McGraw-Hill.

Grace, Dick, *Squadron of Death*, chap. I. Doubleday.

Questions for Review

1. Define the term *reverse control*. Is this a wholly satisfactory term? Give reasons.
2. List the advantages of acrobatics.
3. Describe the making of a 90-degree turn. How do the elevators act during this maneuver?
4. How do you recover from a reverse-control turn?
5. Explain the uses of the sideslip.
6. What is the method of executing a loop? What precautions are necessary?
7. Describe a split S-turn. A wingover.
8. Draw diagram of a roll. An Immelmann. A falling leaf.
9. What principles are involved in formation flying?
10. What are suitable conditions for the practice of acrobatics?

Official Photograph, U. S. Army

FIG. 150. MILITARY FORMATION FLYING

This is an essential part of fighting maneuvers. This is a squadron of Army planes.

CHAPTER XIX

ADVANCED INSTRUCTION IN LANDINGS

A *spot landing* is one in which the pilot attempts to ground his plane so that it will stop rolling at a predetermined spot on the field. Practice in spot landings is given chiefly by way of preparation for forced landings. *Forced landings* are those made necessary by actual or impending engine failure or weather conditions. Frequently they must be made in small fields, or in fields surrounded by high obstacles, where the only possible course for the landing must be followed with great precision. *Cross-wind landings* are landings made at an angle to the direction of the wind.

How to Make Spot Landings. Before you will be able to make landings with any degree of accuracy, you must become thoroughly acquainted with the feel of the plane you are flying, so that you know how to make a mental map of your landing. You must also know how steep the gliding angle should be, so that the plane will roll no farther than the desired distance after it has been grounded.

Spot landings can be made either with or without the use of the engine. In a spot landing under power, the approach should be started at an altitude low enough so that all obstacles may be safely cleared without acquiring the excessive speed which results from a steep glide. A straight approach should, if possible, be made, so that no turns will be necessary while the plane is near the ground. The landing should be made into the wind, if possible. Enough speed must be maintained to prevent stalls. If a power approach is to be made over low obstacles, the plane should be brought down as near the ground as possible, even before it gets to the edge of the field; from that point on, level flight should be maintained. If the ship threatens to undershoot a little when you are making a power landing, open the throttle wide for an instant. This gives you a momentary burst of speed which will

carry you to the mark, besides giving you power control. If, at any time during the approach, it becomes apparent that you are not going to make a good landing, the best plan is to open the throttle and go around the field for another try.

The preferable method of making the approach for a spot landing without power is by a series of S-turns. This method has several advantages. It enables you to keep constantly in view the spot where you are to ground the plane; thus you will be able to tell whether you are going to over- or undershoot. If, for example, you at first miscalculate the speed of the wind so that you are going to over- or undershoot your mark, you will be able to correct this by decreasing or increasing the tightness of your turns.

Methods of Losing Altitude. Frequently, when you come near the mark where you desire to ground the plane, you will find that you are going to overshoot because you have not lost sufficient altitude in the approach. This usually occurs when landings are made in fields surrounded by high obstacles. An increase in the angle of glide might ground the plane at the desired spot, but such speed would be gained that the plane would roll far beyond the point where you wanted it to stop. There are several methods by which altitude may be lost without gaining excessive speed.

If the field in which the landing is to be made is not too narrow, the sideslip is an effective means of losing altitude. As already explained, a sideslip is caused by a bank which is excessively steep in proportion to the amount of turn the plane is making. A long sideslip is dangerous; therefore, one should not be begun at a height of more than 300 feet.

In order to execute a left sideslip, for example, head the plane into the wind and a little to the right of the place where you wish to land. Apply hard left aileron and right rudder. Hold the nose as far above the horizon as can be done without stalling, so that excess forward speed will not be acquired. The plane will fall rapidly downward and sideways to the left. The nose of the plane will continue to point toward the landing place, but there will be a sideslip motion over the ground toward the left. To come out of the sideslip, use firm up aileron, to level the wings, and

rudder out of the slip strongly. You will have lost considerable altitude, without gaining speed. Figure 151 shows a sideslip.

As soon as you have had a little practice with slips, you will be able to continue in one until you come within a few feet of the ground. The plane can be easily and quickly righted after a slip.

"Fishtailing" is another method of losing altitude without gaining excessive forward speed. Fishtailing is a method of slewing the plane from right to left while the wings are still parallel to the horizon, so that height is lost by the resistance which the fuselage presents to the air. This maneuver is effected by pushing the rudder-bar coarsely, first to the right, then to the left. Opposite aileron must be applied after each movement of the rudder in order to keep the wings level. Fishtailing is not usually so advisable a method as slipping, since there is greater danger of stalling.

Elements of a Forced Landing. Any practice which you have had in making precision landings will be of use when you come to practice forced landings. Engine failure is apt to oblige planes to land in limited space. If the plane gives evidence that engine failure is imminent, either by means of the fuel gauges, the tachometer, the sound of the motor, or in other ways, some action should be taken immediately. Even if there is assurance that the actual failure will be postponed for several minutes, no time must be wasted. Any extra engine power should be used to fly about in order to inspect landing fields, so that the landing will not have to be made in the most accessible field, regardless of its suitability. Therefore, the forward movement of the stick to put the plane into a glide should connect itself instinctively in the mind of every pilot with even threatened engine failure.

If the engine stops without giving warning, however, it is still more imperative that immediate action be taken. Under average conditions, a plane will glide approximately a mile over the ground for every thousand feet of altitude. If the plane is several thousand feet up in the air when the engine fails, you will have sufficient time to discover the direction of the wind, the possible landing fields within range, and the best course of approach. On the other hand, if the engine fails at an altitude of a few hundred feet, over country which is entirely unfamiliar to you, you will

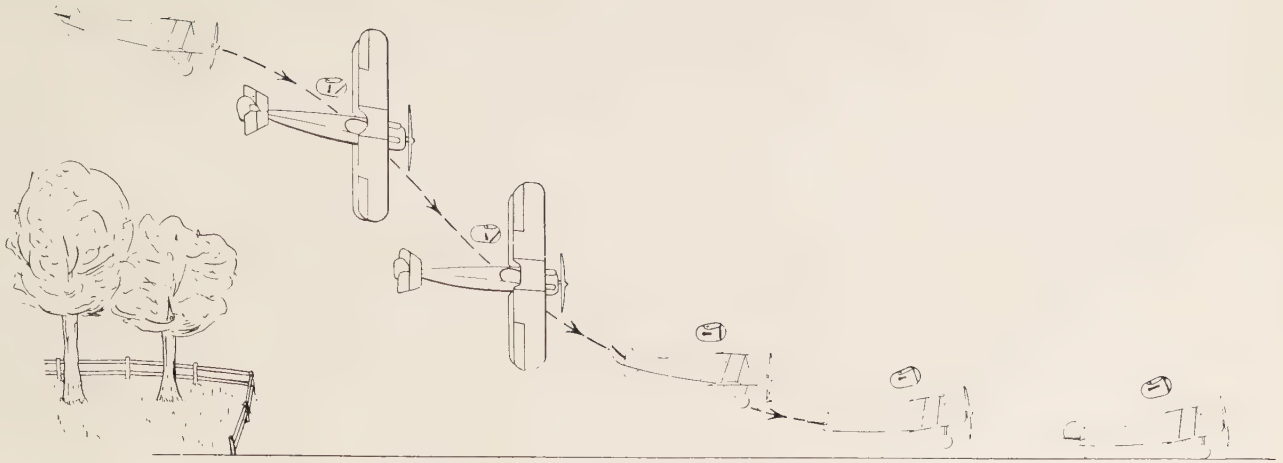


FIG. 151. A SIDESLIP APPROACH

A sideslip is effected by means of a steep bank and hard opposite rudder, with engine throttled. Altitude is rapidly lost as a result. Recovery should be effected while still well above the ground, so that the ship can be straightened out before it is finally set down.

have little time for consideration. Therefore, you must be able at any time to make quick judgments.

A landing made with the engine not turning over is known as a *dead-stick landing,* because the propeller (stick) is dead. A dead-stick landing calls for a sharper angle of glide than normally, since the still propeller creates considerably more resistance than when it is revolving.

Three essentials must be kept in mind during a forced landing. First, you must keep flying speed; no altitude can be wasted in the recovery from a stall. Second, you must know in which direction the wind is blowing, so that the landing may be made as nearly as possible up-wind. Third, you must choose the most suitable field for landing.

Choosing the Best Field for the Landing. The field toward which you head the plane in case of engine failure must be within gliding range. Other essentials are that it should be as spacious as possible and that it should be free from large obstacles. It is convenient if the field is long enough to allow the plane room to roll over the earth after it has been grounded, and to provide enough space to take off again when the engine is repaired.

Large obstructions—ditches, fences, and such obstacles—can usually be seen from the air. Fields which have been newly plowed, or where grain has grown to such a height that it ripples in the wind, should be avoided. Grazing cattle usually evidence a fairly good landing place.

You will probably not be given practice in landing in country which is unknown to you, for such experimenting is apt to damage the plane. Many instructors use the method, however, of taking a student over unfamiliar country and suddenly asking him where he would land if the engine should fail at that moment.

Allowance for the Wind. The direction and speed of the wind can be approximately judged by such indications as smoke, trees, cloud shadows moving over the ground, etc. If the air is calm, a landing may be made in any direction. If the wind is over 10 miles an hour, however, landings should be made into the wind, especially if the field is small or rough.

Moreover, the wind rate must be taken into consideration

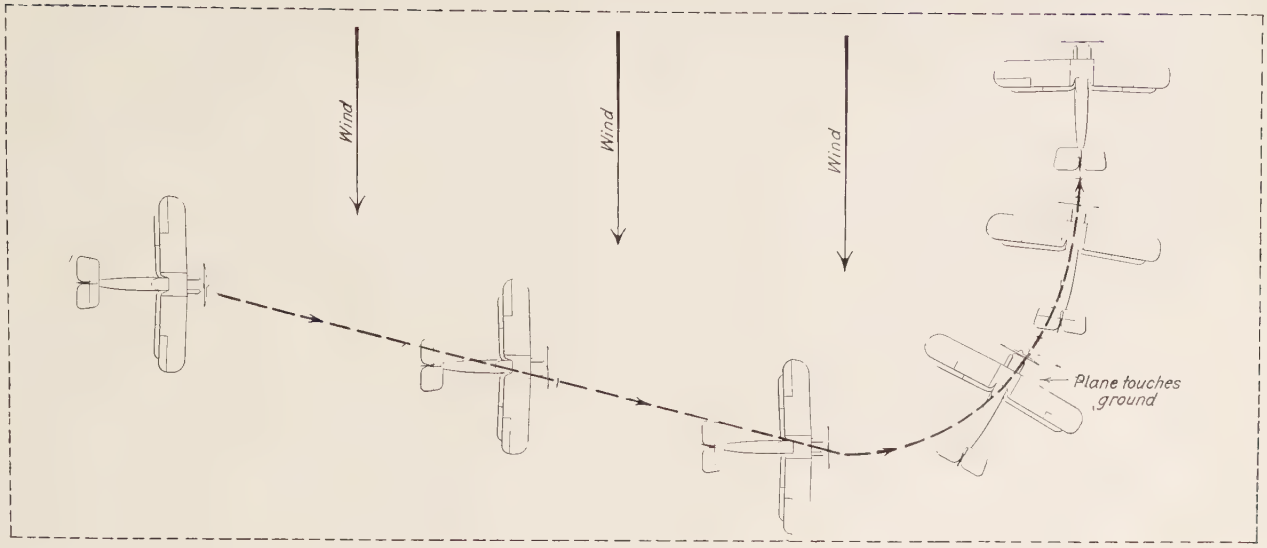
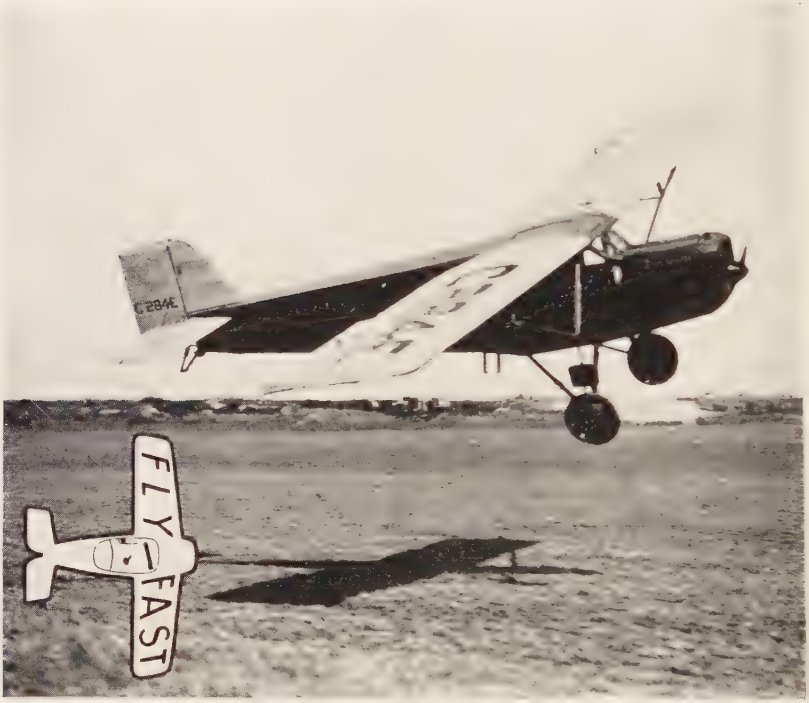


FIG. 152. ONE METHOD OF LANDING CROSS-WIND

The ship is nosed into the wind as much before the wheels touch the ground as is practicable. In reality, the approach here is cross wind, the actual landing being into the wind.

when determining the gliding range of the plane. When gliding into a strong wind, the ground space which the plane will be able to cover will be considerably lessened; the opposite is true when gliding with the wind.



Curtiss Flying Service, Inc.

FIG. 153. COMING INTO THE WIND JUST BEFORE LANDING

Just before making contact, the nose is turned so that the path of the ship through the air corresponds with its path over the ground.

Cross-Wind Landings. Cross-wind landings should be avoided, since they are likely to carry away the landing gear. In emergency, they must be used.

In making a cross-wind landing, the object is not to let the wind sideswipe the wheels across the ground. It is often possible to turn the nose of the ship into the wind just before the wheels touch the ground, as in Figure 152. A photograph of this ma-

neuver is shown in Figure 153. By this means, the path of the ship through the air, at the moment of landing, corresponds with its path over the ground.

Another method of landing cross-wind is illustrated in Figure 154. This method is necessary when landing cross-wind in a

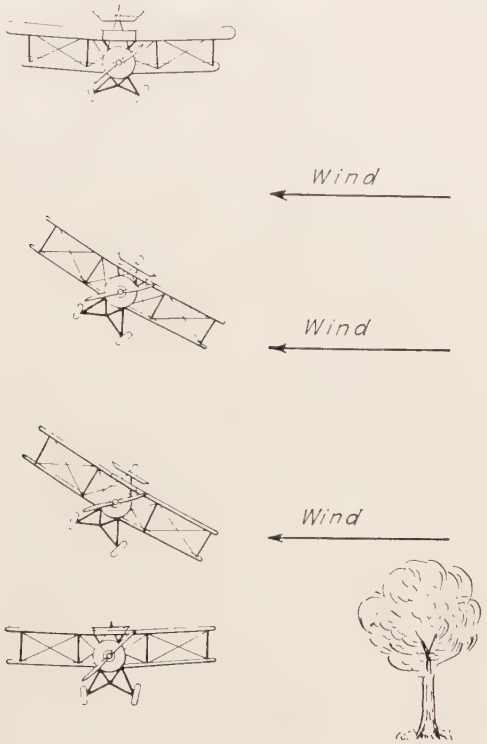


Fig. 154. Another Method of Landing Cross-Wind

The purpose is to give the ship a sideways motion sufficient to counteract the drift imparted to it by the wind. This is accomplished by sideslipping.

narrow field. The plane is given enough sideslip in the direction opposite to the wind to counteract the sideways motion which the wind imparts.

Care should be taken to have adequate flying speed. The ship should have a little excess sideways motion against the wind, up

until the last; so that when the wings are leveled (by use of the ailerons) the momentum will continue, and when the wheels touch they will not be dragged sideways over the ground. When the wings are leveled, the ship is really skidding, and this sideways motion must be sufficient to correspond with the opposite motion imparted by the wind. Be sure to keep the wings level. Throughout the maneuver, be sure that the regular steps of making the landing, by pulling the stick back, are carried out in the usual manner.

The windward wing should, if anything, be a shade lower than the leeward wing. Under no condition should the wind be given an opportunity to "get under" the windward wing. Some pilots go so far as to bring the windward wheel against the ground before the leeward wheel.

Engine Failure at Low Altitudes. If the engine should fail during a take-off at the height of 200 feet or less, no attempt must be made to turn back into the field. A bank of more than 20 degrees occasions such loss of speed that a spin would be inevitable. In such a case, the only thing to do is to nose the plane down immediately in order to keep flying speed. Collision with obstacles is less dangerous than a spin.

Approach. The approach must be steep enough to prevent stalls, but flat enough to allow the least possible loss of height. Never try to flatten out the glide in order to prolong it. Sharp turns, or other maneuvers involving great loss of altitude or speed, should not be attempted. Do not try to go over obstacles which you are not sure of clearing. Avoid them by turns, if possible, or by a sideslip. A straight approach should be made until the landing field is gained.

When you have reached the edge of the field, an S-turn approach should be used. This will allow you to turn into the wind, and at the same time to keep the field in view, so that you may avail yourself of the time by choosing the best point to ground the plane. Slips may be used to lose altitude when you are so nearly above the landing place that there will be no use for the excess height.

Practice of Forced Landings. The instructor will give you some practice in forced landings, probably at your home field. From various altitudes and positions, he will suddenly direct you to cut the gun and make a landing. In such practice landings, you should attempt to ground the plane rather than to make a perfect landing; if the landing is so poor, however, that there is danger of damage to the plane, open the throttle and go around the field again.

* * * * * * * * *

The best way to prepare yourself for the possible necessity of a future forced landing is to make every landing a forced landing; that is, to cut the gun at the beginning of the approach and not to open it again during the maneuver unless this is necessitated. Every take-off should be made so that, in case of engine failure at any point, a turn of not more than 90 degrees would be sufficient to bring the plane to a safe landing place.

Five Things to Remember about Forced Landings:

1. Know at all times which way the wind is blowing.
2. Always have a field in view which would serve you in case of emergency.
3. If possible, fly over the field at least twice, before landing.
4. In a strange field, plan to have a little too much altitude, and slip in.
5. Keep flying speed: fly fast!

SUGGESTIONS FOR READING ON ADVANCED LANDINGS

Studley, Barrett, *How to Fly,* chap. XVII. Macmillan.
Swoffer, Frank A., *Learning to Fly,* chaps. VIII, X. Pitman.
Clevenger, C. P., *Modern Flight,* p. 35. Alexander.
Jones, Byron Q., *Practical Flying,* chap. XXII. Ronald.

Questions for Review

1. Define the various types of advanced landing.
2. Describe the execution of spot landings, both with and without the use of the engine.
3. What is the advantage of the S-turn in making spot landings?

4. When is "fishtailing" employed? What are its advantages and disadvantages?

5. What should you do in case of engine failure?

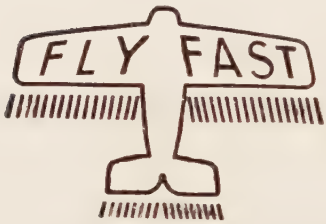
6. What is a dead-stick landing? What must be borne in mind in making one?

7. How should you choose a good field for landing? Get a pilot's advice on this.

8. What bearing has the wind on a forced landing?

9. Describe how a cross-wind landing should be made.

10. What is the best kind of practice for making forced landings?



PART FIVE

SPECIAL INSTRUCTION

CHAPTER XX. THE GLIDER AS A MEANS OF TRAINING

CHAPTER XXI. SEAPLANES

CHAPTER XXII. PARACHUTES

CHAPTER XXIII. CROSS-COUNTRY FLYING AND NAVIGATION

By the time he has come to this point in his instruction, the student will have reached a conclusion as to what use he intends to put his newly acquired abilities. Part Five discusses some subjects which may have special interest for special students.

The opening chapter in Part Five relates to motorless aviation, that is, to gliders and soarers, especially in their application to training purposes. Next follows an exposition of seaplanes and their handling. Chapter XXII tells how parachutes are made and used. The final chapter is devoted to cross-country flying and navigation, a subject which has the peculiar quality of being as simple and easy or as difficult and abstruse as anyone cares to make it.

CHAPTER XX

THE GLIDER AS A MEANS OF TRAINING

The glider is a motorless airplane which is capable of sustaining flight. Some experimentation was made with gliders before the invention of the automobile engine made possible the construction of motored planes. Since the war, Germany has devoted a good deal of attention to the glider, because the Treaty of Versailles restricted her construction of planes with engines. Gliding is now attracting the interest of the European nations and bids fair to be incorporated into regular flight training courses by air schools as a step in instruction. It already is used by some American schools. It is a subject with which all pilots should be familiar.

Gliding and Soaring. Gliding properly means sliding downward; soaring means climbing, or even flying without loss of altitude. Gliding, however, is used as a generic term for both maneuvers. No line of distinction is possible between gliding and soaring, when they merge in level flight. Elementary gliding consists of being pushed into the wind, in a motorless plane, usually from the side of a hill, sliding downward as in a throttled airplane for a few seconds, and landing again farther down the slope of the hill. The ship will glide, as a motored plane does, as long as the lifting power of the wings offsets the pull of gravity and is sufficient to hold the glider in the air. This takes place as long as the angle of glide is steep enough for the force of gravity to sustain the flying speed. Skillful pilots are able to glide for several minutes, if the slope of the hill is long and the wind brisk.

By soaring, however, a motorless plane is able to climb as well as glide. Figure 155 shows a soarer in flight. Soarers have stayed in the air for hours at a time. In order to soar, both rising and horizontal currents of air are made use of. Rising currents of air

are most easily found in hilly regions. The wind, moving in a horizontal plane along level terrain, is necessarily deflected upward by hitting a vertical surface, like the side of a hill. As long as the upward speed component of the rising wind remains equal to the rate of descent of the ship, it can be held at a fixed point above the ground and at a fixed altitude. If the wind rate increases, the plane will climb, or, more accurately, it will be lifted

FIG. 155. SOARER TAKING OFF

This is the second of the three types of glider which the Germans use for training. It is their so-called Prüfling. This machine is capable of sustained flight for a considerable period, under favorable conditions. Notice the shock cord, which has just fallen from the nose of the machine.

to a higher altitude. When the rate of the wind decreases, the reverse effect takes place. Height is gained in duration flights by making figure eights on the windward side of the hill where the rising currents are; or if there is a range of hills, by making S-turns along its ridge.

In order to keep aloft by means of horizontal currents of air, the pilot must not only be skilled in the manipulation of the controls, but also he must be thoroughly familiar with meteor-

ology. A soarer utilizes alternately the swift and the sluggish portions of the air, as a boat progresses with its sail in the wind in order to gain speed and its keel in the water to direct its course. For example, a soarer pilot may effect a zigzag course, by climbing into a rapid current, then turning and diving to gain

FIG. 156. SOARER BEFORE TAKING OFF

This machine is ready to glide from the top of an incline. The shock cord may be seen, attached to the nose. Two boys at the rear are holding against the pull of the shock cord, and will let go at a given signal. The elevators will be leveled off before the start. The instructor stands with his hand on the right wing, balancing the ship. There is no landing gear—merely a skid. The contrivance in the foreground is used for hauling the ship up over the brow of the hill.

speed until the next rapid current approaches. As yet, however, the inadequacy of instruments by which the length and frequency of such currents can be measured prevents the success of soaring flights from being consistent, except by experienced men. Figure 156 illustrates a soarer before taking off. Figure 157 shows one after taking off. Both of these are the secondary type of training ship. The most advanced type is shown in Figure 158.

Construction of Gliders. Gliders are merely airplanes without engines. Two requisites for their construction are that the wing span shall be as broad as possible and that the parasite resistance shall be as little as possible. They are built of extremely light material, with a fuselage short in proportion to the width

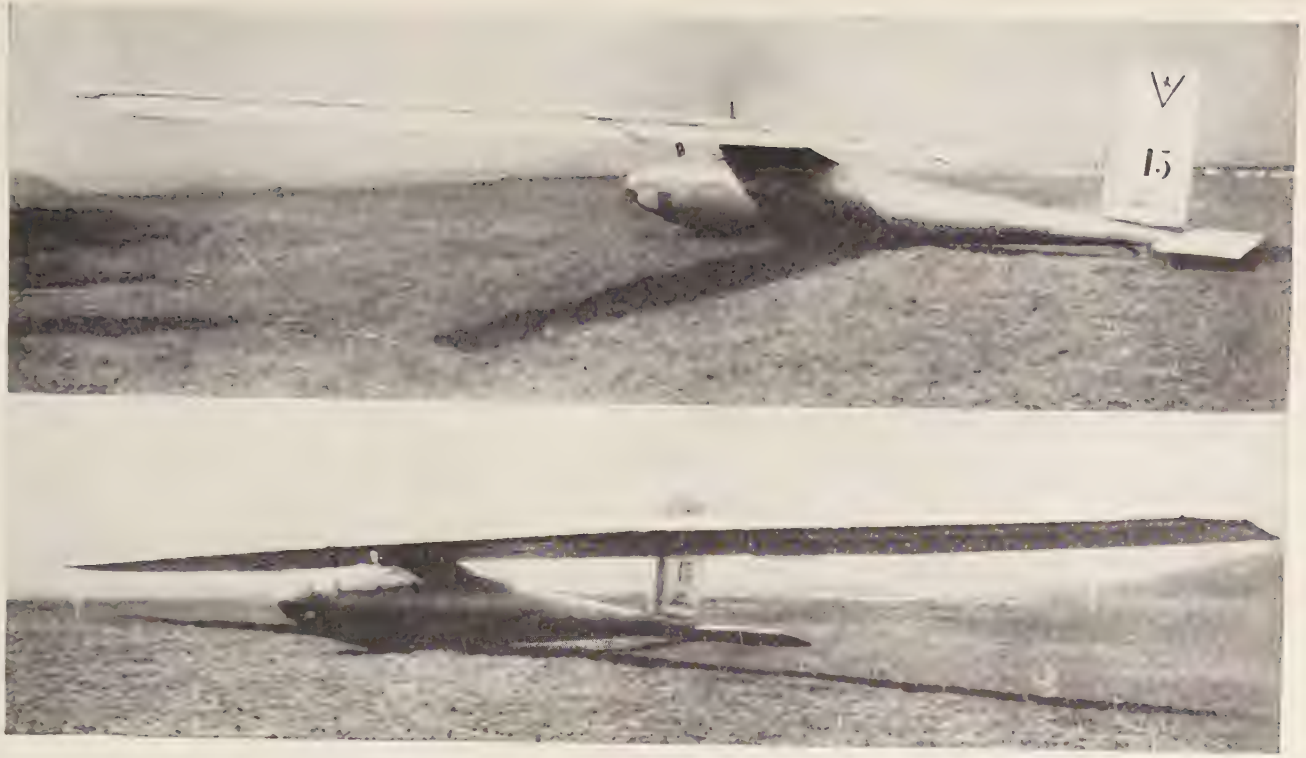
National Glider Association, Inc.

FIG. 157. A SOARER, OR "SAIL PLANE"

This machine has just taken off. The men with the elastic end may be seen. Soarers have made flights of many hours in length.

of the wings, and are usually of monoplane construction, in order to obviate the necessity of any struts.

Various peculiar types of planes have been experimented with as gliders. The one in common use for initial training has open fuselage built of two strips of wood bound together by lattice work. Experiment has been made with those having tails in front of the wings, flapping wings, etc. In the second, or more advanced



Roemryken Berge

FIG. 158. ADVANCED TYPE OF SOARER

This is the most advanced type of machine used for soaring, being extremely low in parasite resistance. Unlike the elementary models, it has no struts. Notice the ailerons; also the pilot's head.

type, the pilot sits in a streamlined cockpit directly in front of the wing.

The control surfaces are similar to those in a motored airplane, and are operated by a rudder-bar and stick. Although some gliders are equipped with light landing wheels, these offer resistance to the air, and they make it dangerous for the plane to land on the side of a hill. Therefore, most gliders have a landing gear consisting merely of a single runner attached in place of wheels.

National Glider Association, Inc.

FIG. 159. GLIDER IN POSITION FOR THE TAKE-OFF

Men are ready to pull forward on the two cords which lead from the nose of the glider. The pilot is not in his seat.

Soaring may be done if the pilot is extremely skillful with a glider. Usually, however, soarers are built especially for the purpose, with broader span and wider and more sensitive control surfaces, so that their functioning may be delicate and accurate.

How to Glide. Recently the dual control system has been made possible for gliders. Normally, however, instruction is given from the ground, since the absence of the noise of the motor permits conversation.

In order to take off, the glider, having no motor, must employ some force not its own. The most effective method is by the use of elastic cable, or "shock cord," attached to the nose of the ship by a quick-release hook. By the use of this cable, the ship is shot from the side of the hill as if from a sling shot. A second piece of cable is attached to the tail, and is held by several men stationed behind the plane. The main cable is fastened at its center to the nose of the plane, by the use of a hook and a ring.

National Glider Association, Inc.

FIG. 160. TAKE-OFF OF THE GLIDER

The men have run forward, pulling the ropes, and the glider has been snapped into the air. In a glider of this type, a flight of thirty seconds is considered a good flight.

Each end of the cord is held by three or four men. See Figures 159 and 160. The men walk away from the glider until the cable becomes taut. At given signals, the men with the nose cable run ahead, pulling the glider after them. At a signal from the pilot the cord at the tail is released and as the machine snaps into the air, the tension on the nose cord is, of course, released also and it drops away from the hook.

The control of a glider when it is in the air is much the same as that of a plane with an engine, except that no slipstream or

torque is present. Whether or not turns can be made depends upon the length of time the glider is in the air.

The landing of a glider is a comparatively simple matter. Due to the broad span of the wings, the stalling speed of a glider is extremely low, and landings may be effected at a ground speed of only a few miles an hour. This allows adequate time for even a poor flyer to make correct use of the controls. Moreover, the weight of a glider is so little that one has been known to land safely on telephone wires!

Purposes of Gliding. Gliding or soaring has for several years had great vogue in Europe as a sport. A German pilot says of it:

". . . I am unable to describe the sublime pleasure one experiences in gliding over hills and valleys, silently, like the eagle, cruising or hovering, rising or descending, at will. The ample controllability makes you feel like him, master of the air. The constant alertness, watching for favorable air currents and studying their relations to the varied scenery below, provides thrill and challenge. . . ."

Gliders afford excellent opportunity for experimentation. Applicability of untried theories of aerodynamics may better be tested in the air itself, than in artificial wind-forming devices. Gliders are able to fly through air disturbances and over mountainous country where the use of motored planes is fraught with danger.

An important function of the glider is as a means of flight training. For this purpose it has several qualifications. First, gliders are available to a great many people because of their low price (about $500). They are, however, more apt to be used in groups rather than by individuals, and for a number of reasons. Moreover, a glider is safe. It does not take the student at any great speed nor high above the ground, until he becomes fairly proficient. Its landing speed is so low that the maneuver of grounding the plane (so difficult in motored flight) becomes an operation involving little risk. These qualifications make safe the prediction that, in a few years, flight in motorless planes will be available to all the youth of the country.

* * * * * * * * *

Gliders are capable of furnishing two steps in a pilot's training. First, they are useful in initial flights. They enable the student to acquire the feel of the controls at the minimum of cost and risk. Aside from this, soarers may add to the experienced pilot's knowledge a fund of information which would otherwise be unavailable. Incomplete acquaintance with the principles of meteorology now makes motored flight through serious air disturbances dangerous. If, on the other hand, the airplane pilot becomes more familiar with the atmosphere, by flying a glider, this lack of knowledge may be largely removed. Storms and mountainous regions would be less formidable to the airplane if its pilots knew how to estimate the length and frequency of air currents, in order to avoid them or to make use of them.

SUGGESTIONS FOR READING ON GLIDERS

Weiss, J. B., *Gliding and Soaring Flight,* Marston.

Klemperer, Wolfgang, *Soaring Flight,* Smithsonian Institution. (1927, Vol. 8, pp. 221-241.) Reproduced in pamphlet form by Government Printing Office in Washington, 1928.

Questions for Review

1. Write a report on gliders previous to 1920.
2. Differentiate between gliding and soaring.
3. Is wind necessary for gliding? For soaring? What are the ideal conditions of wind and terrain?
4. Why is a knowledge of wind currents necessary in soaring?
5. Draw a diagram of an elementary training glider.
6. What is the type of landing gear normally used in a glider?
7. Describe the method by which a glider takes off.
8. How does the control of a glider differ from that of motored planes?
9. What advantages has the glider as a means of instruction?
10. Interview a pilot as to the possibilities of "dynamic soaring."

CHAPTER XXI

SEAPLANES

The operation of seaplanes in the air is practically identical with that of land planes. In the water, however, the manner of maneuvering seaplanes differs from that in which land planes are handled on the ground. These points of difference should be well understood by a pilot, since seaplanes and amphibians offer an increasingly important means of air travel.

Taxying. An important difference between seaplane and land plane taxying rests on the fact that water is less stable than earth, and the seaplane is able to get little purchase on the water. When a seaplane is afloat, it is seldom at rest, as a land plane is when standing on the ground; it is moved about on the surface of the water by wind, tide, and current, and by the force of the propeller if the engine is running. These factors all tend to throw it off its course. If left alone, a seaplane always heads into the wind.

If the pilot desires to taxy in a straight course, it is comparatively easy to do so as long as the plane is headed up-wind. To taxy across wind requires maintenance of rudder in the direction which will offset the plane's tendency to swing into the wind. (See Figure 161.) It is necessary to make coarse use of the ailerons as in land plane taxying, and to open the throttle so that there will be enough slipstream to make the rudder sensitive.

The stick must be held well back in taxying, so that the front end of the float will not dip under the waves and splash on to the engine.

In order to make turns in seaplane taxying, the control surfaces are used in the same way as on landplanes. The throttle must be used to offset the force of the wind. In order to make a turn out of the wind, the throttle must be opened enough to counteract the tendency to turn the plane into the wind. When a

turn into the wind is desired, however, the throttle should be closed, since the plane will be turned by the wind itself. (See Figure 161.)

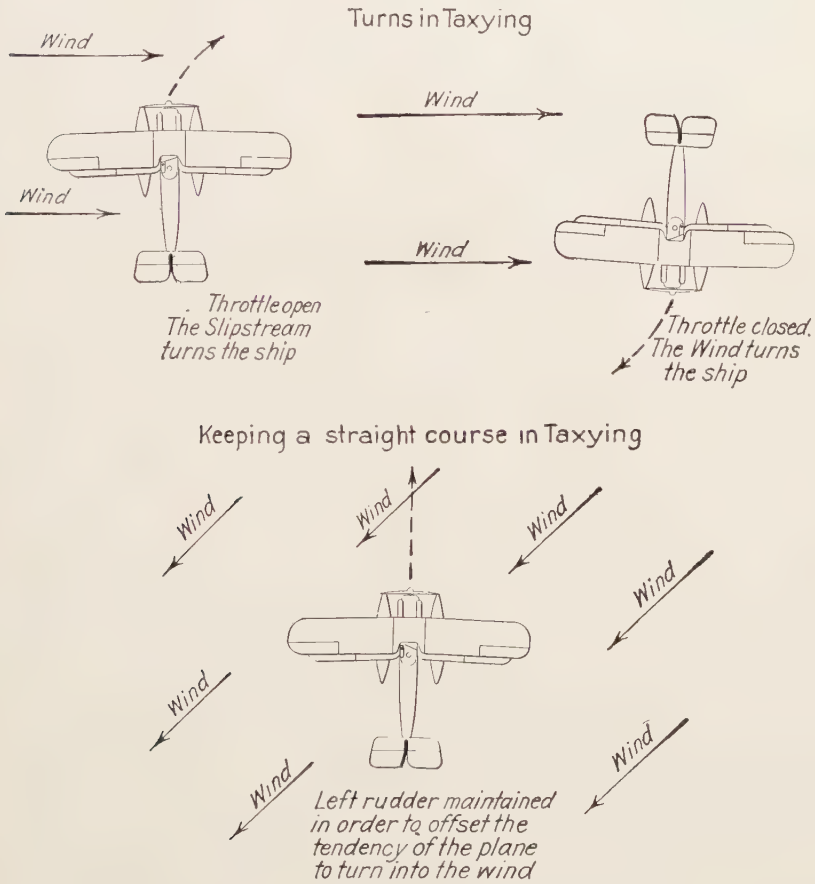


Fig. 161. The Taxying of Seaplanes

These operations depend upon the fact that the seaplane, of itself, tends to turn head into the wind. Taxying in stiff breeze calls for skilful use of both rudder and throttle.

The student must watch the water ahead for any obstacles which might injure the floats. Even a slight floating object will puncture them, if the ship is traveling rapidly. The nose should

Official Photograph, U. S. Navy

FIG. 162. COMING UP ON THE STEP

To bring a seaplane on to the step, that is, to make it operate like a hydroplane, rather than like a displacement boat, the stick must be pulled back and then forward. Sometimes a rocking motion is used. Torpedo and bombing plane. (Note that position of ailerons does not agree with control diagram.)

be swerved occasionally so that the surface which is normally hidden by the "blind spot" may be inspected. Submerged rocks must be carefully watched for.

Taking Off. The manner of taking off a seaplane is somewhat similar to that of land planes. But the float, when submerged in the water, would present too much resistance to allow the plane to gain flying speed. Therefore, before flying speed can be acquired, the plane must be raised so that the float is skimming along the surface of the water with air between the float and the water, on the principle of a hydroplane. This position is called "on the step." (See Figures 162 and 163.)

The purpose of the step, which is positioned between the forward and the aft planes of a hydroplane, is to permit air to go back under the hull while it is traveling at high speed. This reduces the wetted surface, and also reduces the displacement of the floats when under way. As the float rises, air is able to pass in behind the step, since the outboard openings to it are open to the atmosphere. This tends to break any suction of the water which would otherwise hold the float to the surface of the water. As the speed of the ship increases, the area of the wetted surface decreases, and the surface friction is also decreased. The step also permits the entire after portion of the float to lie at the proper angularity to the surface of the water, so that the reduction of wetted surface may be attained at the earliest possible moment, and so that the angle of attack of the wings may be great enough to give the ship sufficient lift to take off.

In order to bring the float above the surface two control movements are made. First the stick is pulled back and the throttle opened. Gradually the plane gains enough speed so that the bow of the float is lifted from the water. Then the stick is pushed forward again. This motion does not depress the nose since the force of air created by the forward movement of the ship suffices to hold the bow of the float up. As a matter of fact, the forward movement of the stick lifts the heel of the float. The stick should then be placed in neutral as soon as the ship is "on the step," in order to hold this skimming position. Sometimes the ship is "rocked" back and forth, to assist it in taking off.

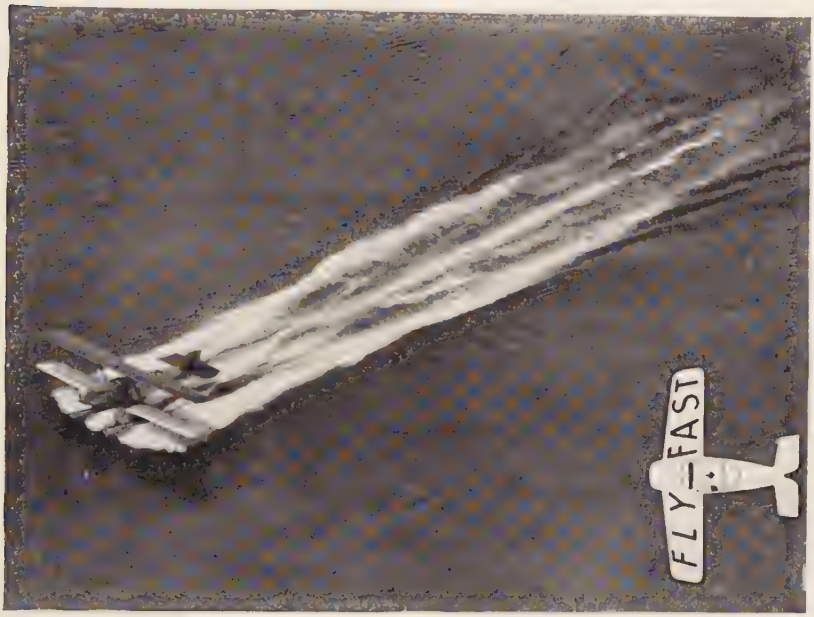
When flying speed is attained, the take-off is continued in the

FIG. 163. ON THE STEP: ABOUT TO TAKE OFF

The ship is on the step, and flying speed has all but been reached. This is a British Fairey Seaplane fitted with Napier Lion engine.

same way as with land planes. The stick is pulled back slightly to aid the plane in leaving the water. The plane is then held in level flight long enough to gain speed for the climb.

It is extremely important that the directional stability of the plane be maintained. If the ship is swerved considerably out of the wind, it is better to land again and start a new take-off.



Official Photograph, U. S. Navy

FIG. 164. HEIGHT ABOVE SMOOTH WATER IS DIFFICULT TO ESTIMATE

When the surface is smooth, or almost smooth, as in this picture, it requires much practice to enable the pilot to determine where he should level off, in landing.

In order to keep the plane nosed into the wind, it is a good idea to sight a landmark, if any is available, before taking off. Care must also be taken to preserve lateral stability.

Take-offs in rough water are difficult. The waves make the plane bounce; a bounce must be corrected by a forward movement of the stick to cut short the rebound, and a quick backward movement of the stick to offset nose-heaviness. The pilot must

take great care to keep the bow of the float from nosing under the water. In short, the plane must be practically stalled off the water, as a land plane is from rough ground.

Landings. For a seaplane landing, the direction of the wind is indicated by the water. Wave lines usually run perpendicular

Official Photograph, U. S. Navy

FIG. 165. SEAPLANES IN FORMATION

It is common practice in the Navy to fly seaplanes in formations of various sorts. This is a "torpedo attack" by torpedo and bombing planes during fleet maneuvers at Panama.

to the wind; this angle is not, however, always exactly 90 degrees. Therefore, it is better to judge wind direction by streaks in the water. These streaks are visible whenever the velocity of the wind is sufficient to affect the landing considerably. They run parallel to the direction in which the wind is blowing. When the surface of the water is smooth, it is extremely hard to judge

one's height above it. (See Figure 164.) The shore line, or a vessel, will serve to indicate the level of the water.

A correct seaplane landing which corresponds to the three-point landing is called a "full stall landing." The plane should first hit on the heel of the float and then ease forward after speed has been lost, until the float is level in the water. The execution of a seaplane landing is exactly similar to that of a landplane. Care must be taken to prevent tail-high landings, especially in rough water, where the rebound will be pronounced. In landing on rough water, the plane should be completely stalled four or five feet above the surface.

"Sailing" a Seaplane. A seaplane, unlike a land plane, is capable of propulsion by the wind alone, before taking off. In other words, it can be maneuvered over the surface of the water much as a sailboat is, by using the force of the wind. The method of doing this will come natural to a yachtsman.

A good breeze will have a turning effect on the ailerons and rudder. In the case of ailerons, the situation is not unlike that described under the subject of "aileron drag," in the chapter on Taxying. The ship, while headed into the wind, and while still under way, can be steered at an angle to the wind—in other words, it will tack. The aileron is depressed on that side to which the pilot desires to head. The rudder is also used, to steer with. The depressed aileron acts as the sail, while the raised aileron is not caught by the wind.

* * * * * * * * *

Seaplanes offer exceptional opportunities for formation flying, such as is illustrated in Figure 165. This is made possible through the ability of seaplanes to take off simultaneously, without danger. The take-off of seaplanes is illustrated in Figure 166. The ships shown in this picture are used for military purposes. Flying boats, rather than float seaplanes, are preferred for private ownership. Such a boat is shown in Figure 167.

SUGGESTIONS FOR READING ON SEAPLANES

Chatfield and Taylor, *The Airplane and Its Engine,* chap. XIII. McGraw-Hill.

Studley, Barrett, *Practical Flight Training,* chaps. XV and XVI. Macmillan.

Official Photograph, U. S. Navy

FIG. 166. SEAPLANES CAN TAKE OFF IN FLYING FORMATION

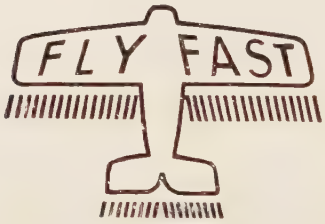
This picture shows only three ships, but many more may take off simultaneously. Torpedo planes "on the step."

FIG. 167. A MODERN FLYING YACHT

This is the most luxurious type of aircraft. It was designed by Anthony H. G. Fokker. It is sometimes equipped as an amphibian.

Questions for Review

1. How is a seaplane taxied?
2. Discuss the use of the stick in taxying.
3. What is the method of taking off in a seaplane? When is "rocking" used?
4. What is a hydroplane step, and how does it work?
5. Why is it that a seaplane always tends to head into the wind?
6. How is a take-off in rough water accomplished?
7. What indicators of wind direction tell the seaplane pilot how to come in for a landing?
8. How is a landing made when the water is absolutely smooth?
9. How are landings normally made? How are they made in rough water?
10. What is meant by "sailing" a seaplane?



CHAPTER XXII

PARACHUTES

By means of a parachute the pilot and his passengers may drop through the air with comparative safety from a plane which is about to crash, provided the altitude is sufficient. As may be seen from Figure 168, a number of people can jump at about the same time. The parachute consists of an umbrella-like arrangement, built up of pieces of cloth. These are made in gores, so that the parachute is hemispherical in shape when open. It is attached by a harness of lines, known as shroud lines, to the body of the user. The cloth presents a sustained surface to the air and retards the speed of the drop. Every pilot should know how to use a parachute. Any flight is made safer by wearing one. The construction of a parachute is shown in Figure 169.

Use of Parachutes. At present parachutes are used chiefly by military pilots and by "stunt men." United States Army and Navy pilots are obliged to be equipped with parachutes. In war, planes are often entirely crippled during flight by bombs or bullets which either destroy the lifting surface or set the fuel tanks on fire, so that pilots have no chance of escape except by dropping into the air.

Commercial and private planes, on the other hand, are only beginning to make use of parachutes. In the first place, considerable time is required for the pilot to get out of the cockpit and jump into the air, where he opens his chute. Unless all the controls become useless, the pilot usually attempts to regain command until he is so near the ground that there is no longer time to leave the ship. Transport planes usually carry so many passengers, and have such narrow doors, that there is rarely time for all the people in the plane to escape. Nevertheless, a device has been invented by which the pilot, by pressing a spring, releases all the passengers, equipped with self-opening parachutes, through trap

Russell Parachute Company

FIG. 168. PILOT AND PASSENGERS CAN ALL COME DOWN TOGETHER

Parachutes are becoming more and more common, as aviation develops. To him who knows how to use it, the parachute is merely a life-preserver.

Russell Parachute Company

FIG. 169. THE CONSTRUCTION OF A PARACHUTE

The method of sewing together the "covering" is shown, also the "shroud lines."

doors in the bottom of the fuselage. Transport lines are beginning to equip their planes with parachutes.

The Pack and Harness of a Parachute. Numerous types of parachutes are in use; of these the most effective is perhaps the one recommended by the United States Air Service. This type is designed to be worn throughout the flight by the pilot (or passenger). It has a pack resembling a pad or pillow, in which the parachute itself is carried. These packs are used, in the ship, for seat cushions. (See Figure 170.) Some types are worn on the shoulders or on the backs of pilots (especially of lighter-than-air craft) who have to walk about. (See Figure 171.) After use, parachutes can be repacked with little difficulty.

The pack is strapped to the pilot's body by means of a harness made of linen webbing. The harness usually goes over the shoulders and around the legs in such a way that the jerks resulting from the opening of the parachute will not injure the pilot. The harness is strongly secured at its joints with metal fastenings. It is adjustable. Attached to the harness, so that it is easily accessible, is a ring. This is attached to the rip cord of the "chute." By pulling this ring, the parachute is released from the pack. In case the pilot falls into the water, or on the ground when there is a strong wind, the harness may be easily removed.

Construction of the Parachute. The parachutes used for military purposes are almost always made of silk; those for commercial work are of cotton. They are usually about 24 feet in diameter. Sometimes a pair of parachutes is used for training purposes, in order to insure safety. A small vent hole at the top has been found to offset the tendency of the parachute to sway from side to side during the drop, and to minimize the shock when the parachute opens.

The parachute is attached to the harness by means of a series of heavy lines, made either of silk or of cotton. These are so arranged in the pack that there is no danger of their fouling when the rip cord releases the chute.

Some parachutes are provided with a "pilot chute." This is a miniature parachute, and is attached to the top spring as soon as the main parachute is freed from the pack. It is caught by the air and carried away from the plane or from the body of the

Fig. 170. A Parachute Harness

This harness goes across the arms and legs of the pilot or passenger in such a way that no part of his body will be wrenched during the drop. The parachute itself is packed in a case and used in flight as a seat cushion. The ring which is pulled to release the chute from its case is seen on the left side of the harness.

FIG. 171. SHOULDER TYPE OF PARACHUTE

One advantage of this type of chute, which is manufactured in Italy, is described by its makers as follows: "Quick declutching: By case of landing with a windy weather, or near a sea, the 'Salvator D' Air Chute can be immediately declutched and its user remains therefore immediately free and healthy. That prevents from being drown with on the soil, or being dragged into the sea."

falling man. As shown in Figure 172, it serves to prevent suspension lines or other members from catching and becoming entangled with the plane or with the aviator's body.

Irvin Airchute Company

FIG. 172. OPERATION OF THE "PILOT CHUTE"

The pilot chute serves to open the main chute, and to keep the lines clear. Two men are about to execute what is known as a "lift-off" from the wings of a bombing plane.

How to Use a Parachute. Drops may be made from any part of the plane and with the plane in any position. To open the parachute, the ring on the top cord is jerked. The process of unfolding requires approximately only 2 or 3 seconds. Some parachutes are packed in a container which is attached to the side

of the fuselage. This is known as the "exhibition type" of parachute; it is largely used by stunt men, but seldom by pilots.

The usual and safest time to open the parachute is immediately after clearing the ship, unless an emergency arises in which

Irvin Airchute Company

FIG. 173. FALLING FREE

The pilot chute serves to open the main chute, and to keep the lines clear. The practice of jumping before opening the chute saves time in leaving the plane and prevents all possibility of the parachute's catching on the plane.

it is necessary to make a long free fall before pulling the rip cord. The practice of daredevils who try to drop to a point just above the ground before opening their chutes is, of course, to be condemned. Nevertheless, the complete reliability of well-made para-

chutes is illustrated by the feats of countless pilots who, to escape a burning plane or to avoid the drift caused by strong winds, have "fallen free" for a thousand feet or more before pulling their rip cords. (See Figure 173.)

The sensations of coming down are not so nerve-racking as one might expect. The jerk caused by the opening parachute may be extremely uncomfortable, to be sure, in spite of the careful arrangement of the harness, but this is not serious. Throughout the fall, the earth has the appearance of coming up to meet the pilot, while the landing is like "jumping stiff-legged from a table."

* * * * * * * * *

Parachutes have not yet come into universal use. Student pilots are seldom given practice in parachute jumping, since this seems to involve an unnecessary risk. Doubtless, when chutes have been perfected so that they may be used with even greater facility than at present, this will be more prevalent.

SUGGESTIONS FOR READING ON PARACHUTES

The catalogues put out by the manufacturers of parachutes are the most valuable literature on this subject. See also current articles in aviation magazines.

Questions for Review

1. What is the purpose of parachutes? Consult a pilot as to their value.
2. Does it appear to you that parachutes will be widely used in the future? Why?
3. Why are parachutes especially adapted to military purposes?
4. What objections are there to the use of parachutes? Are they adaptable to the use of passengers in a closed plane?
5. Describe the pack and harness of a parachute.
6. Define rip cord, pilot chute, shroud lines.
7. How is the parachute operated, in ordinary use?
8. How is tangling of the parachute-user avoided?
9. Under what circumstances is it desirable to "fall free" for a considerable distance before opening the chute?
10. Interview a pilot as to when to use a parachute and when to stick to the ship.

CHAPTER XXIII

CROSS-COUNTRY FLYING AND NAVIGATION

Cross-country flying includes all flights over land which extend more than a mile or two away from the home field. Navigation is the science of plotting and following courses across land or water by means of observing terrestrial objects, dead reckoning, or by astronomical calculation.

Now that airways have begun to complement railways in the transporting of passengers and mail, cross-country flying and navigation are of increasing importance. For this reason, even the private pilot is better equipped if he possesses some knowledge of flight over unfamiliar country, of the application of navigation, instruments, and of the mathematical principles in accordance with which courses are set.

Study of Map. Your first cross-country flights will probably be short and directed largely by observation of landmarks. Before starting on any flight across unfamiliar territory, you should study a detailed map of the region.

There are two objectives in studying a map: first, to show you the best route to follow in order to arrive at the desired location; and second, to familiarize yourself with the terrain surrounding your chosen course. The route should, of course, be planned to approximate, as nearly as possible, the shortest distance between the starting point and the intended place of arrival. There are, nevertheless, two modifying factors to be considered, and these will frequently oblige you to plan your course so that it deviates from the shortest possible route. The first of these is the necessity for having suitable landing places at intervals along your path. It would probably be disastrous, if engine failure should force you to earth when you were flying over a large city or a broad expanse of mountains. The second factor which should be taken into consideration in planning your course

is the frequency of landmarks. If you are to fly by means of landmarks, you must be able, having overtaken one outstanding topographical feature, to see the next one. Therefore, do not plan your route across barren country. In long flights, of course, it is not practical to try to follow such frequent landmarks. In that case, the compass must be used in going from one landmark to the next.

For a long flight, your course must be planned with a view to the endurance of the plane. Your instructor will tell you how much fuel the motor consumes per mile. You must then arrange your route so that you will be able to get new fuel as frequently as is necessary. Make sure in advance that gasoline can be procured at the fields in which you intend to land.

When you have chosen the best route, take a pencil and draw a straight line between each two landmarks on the map. The series of lines will mark a zigzag path passing near cities, past railroad or river junctions, lakes, and similar prominent points, or running along outstanding railroads and streams. In this way you will be able easily to follow the course that you have planned by watching the map during the flight and comparing it with the passing terrain.

After you have decided upon the route, study the map in order to become thoroughly acquainted with the nature of the terrain over which you will pass. You must know where the landing places are near together and where there are long stretches without suitable landing fields. Moreover, if you lose your way, you should be able, without recourse to the map, to determine approximately where you are.

Problems of Map Making. Since the map is the most important part of his navigational equipment, the pilot should know something about how it is constructed. It might be supposed that with safe airplanes flying over properly marked and equipped airways, nothing further could be desired; however, just as surely as marine insurance companies require that ships carry a complete set of nautical charts, showing the location of lights, buoys, and other aids with respect to channels, obstructions, and harbors, so surely will safety in air transport demand similar maps, showing the location of beacons and other aids with respect

to airways, airports, and the features of the terrain. Also, the greater part of civil flying is now, and will continue to be, off the airways, and for this class of flying accurate and adequate air maps will prove even more indispensable.

Accuracy is the great problem of cartography. The fundamental basis of this accuracy lies in the proper selection of the mathematical framework or projection upon which the map is constructed, i.e., the system of lines representing latitude and longitude. It is, of course, obvious that the spherical surface of the earth cannot be truly represented, with all of its properties, on the flat surface of a map. In other words, we cannot step on half an orange to flatten it without causing it to split in several places. There are many mathematical ways of compensating for these splits; the number is legion. Each method retains some desirable and necessary quality, but must perforce sacrifice others. The projection chosen for a given map or series of maps depends upon the quality or property most desired for its intended use, together with the extent and proportion of the area, the latitude covered, scale, etc.

There are numerous types of projection, the nature of which is too technical for discussion here. This is a matter for the cartographer. He also has the problem of filling in the detailed information required by the flyer. The amount and nature of the information that can be shown will vary with the scale which must be adopted. On large scale maps, an exact picture of all physical features, drainage, extent and shape of cities, number of railroad tracks, etc., may be reproduced just as they appear on the ground. As the scale becomes smaller, only the more important of these features may be shown, the others becoming generalized symbols, or if necessary, being eliminated altogether.

Any map for navigational work must include, in their geographically correct positions, the principal physical and cultural features—shore line and rivers, railroads, principal cities (the number being determined by legibility and the scale of the map), elevations, etc. For air navigation the map must also show the location of airports, together with the aids to navigation, such as revolving and blinker beacons, radio beacons and radio marker beacons, airway radio stations, the magnetic variation, and such

other prominent features serving as landmarks, as the scale will permit.

The following features are shown by Rand McNally and Company in their air maps:

Established Airways are represented by solid lines. The courses, or bearings (which are given for both directions), are mean magnetic courses, and must be further corrected for leeway and compass deviation.

Airways Established by the Department of Commerce are equipped, or to be equipped, with intermediate fields and beacon lights maintained by the Department. A few radio directional beacons and radio marker beacons have also been installed, and others are to be installed in the near future. Due to extensive construction, many new fields and beacons will be added, and many others relocated.

Revolving Beacon Lights are usually spaced about ten miles apart, the spacing varying with the nature of the terrain. Course lights, showing a directional beacon along the airway, are being installed on the platform below the revolving beacon and not only indicate when the pilot is on course, but also flash a distinctive signal identifying the field or beacon.

Fixed or Blinker Beacon Lights are used under certain conditions to supplement the revolving beacons, and on locations where commercial current is not available. They are usually spaced only a few miles apart.

Private Beacon Lights off the Airways, that have been certified by the Department of Commerce, are also shown.

Radio Stations. Only those stations considered as Aids to Navigation have been shown. These may be equipped for handling weather reports and other air information, for direct communication with planes in air traffic control, or both.

Due to the present state of change and reallocation, call letters have been omitted. It is suggested that pilots add to their maps call letters that may be of value to them.

Radio Directional Beacons transmit, along the airways, radio signals which will inform the pilot if he is on course, or, if off the course, he may know to which side he has deviated. For example, on an airway running east and west, the letter "T" may be heard in Morse code when on the course; the letter "A" when north of the course; and the letter "N" when south of the course. It is believed

that the visual instrument system, which is now in course of development, will soon replace the sound signals.

Radio Marker Beacons are low-powered stations transmitting a distinctive signal of limited range at the point where the change of course occurs between two radio directional beacons.

For Cities of More than 5,000 population, the comparative mass is shown to enable the pilot readily to identify the larger centers of population. These serve as outstanding landmarks by day, and at night, even in foggy weather, the glow of their lights may serve as a guide.

Elevations are given in feet, an "X" representing a peak or other relatively prominent elevation, and a "±" representing other typical elevations. In the event of any large area where no elevations are given, it may be understood that surveys of the area are not yet available.

There has been considerable discussion as to the relative merits of strip maps, showing only a narrow strip of country contiguous to the airway, and area maps, showing an entire state or other convenient area unit. Due to the fact that, according to the Department of Commerce, approximately 90 per cent of the nation's flying is now and probably always will be off the charted airways, and because it is so easy for pilots, voluntarily or involuntarily, to fly entirely out of the area covered by the strip map and so be left without any map of the country beneath them, the Federal Board of Surveys and Maps has now adopted the area map scheme in place of strip maps.

Study of Weather Conditions. Your first cross-country flights should be made under propitious weather conditions. When practice has accustomed you to following unfamiliar routes, fair weather will not be so essential to your safety. Nevertheless, planes have not yet been built to brave whirlwinds, nor instruments invented which will allow the pilot to land in a ground fog with any degree of safety.

Cross-country flights should be made in clear weather, if possible. Haze prevents landmarks from being visible. A low ceiling necessitates flight close to the ground. This is dangerous in case of engine failure, since the plane's gliding distance is necessarily shortened. If the low ceiling is caused by a layer of clouds, flight should not be attempted in the clear air above the

layer, where the ground cannot be seen. (See Figure 174.) Fog is the most dangerous of all weather conditions. Never start to fly in a fog. If one approaches while you are in the air, land before it overtakes you.

From any available data, you should ascertain the average wind condition in the country you are to traverse. Take care to avoid regions where there are sudden or upward currents of air. If the daily weather map or the barometer indicates that there will be a high wind or storm during the day, it is better to postpone your intended flight.

Do not start your first cross-country flights so late in the day that it will be dark before you arrive at your destination. Night flying is a science in itself and should not be attempted until you are familiar with the principles of navigation.

The First Cross-Country Flight. After you have plotted your course on the map and have made sure that the weather conditions are favorable, you will take off, in order to make actual experiment with cross-country flying. Your first flights should not last more than an hour or two.

The altitude at which you will fly should be largely determined by the velocity of the wind and the nature of the terrain. In general, the rate at which the wind travels increases with increasing altitude, and vice versa. For this reason, long-distance flights are made at greater heights when going with the wind than when going against it.

Over rough terrain, fly at a considerable altitude, so that the plane will not be retarded by local air disturbances. On a calm day, it is safe to fly as low as 2,000 feet, if good landing fields are plentiful. But if it is necessary to fly over long stretches, where no landing places are available, the plane must have sufficient height to glide, with a dead motor, to a safe place in which to land.

A climb indicator will be useful for this work. It shows instantly any change in altitude and the rate, in thousands of feet per minute. It is of great help in maintaining the desired altitude in cross-country flying, and is of outstanding value in mountainous country where wind currents are liable rapidly to change the altitude of a ship. Its indications do not depend upon the

FIG. 174. FLYING OVER CLOUDS

For beginners in cross country flying, low-hung clouds are dangerous, especially if the region is one in which there is much air traffic. Flying above them does not give safe altitude. The photograph shows a British "Moth."

angle of climb, but upon the rate of change of altitude, enabling the pilot to climb as rapidly or to descend as slowly as possible without stalling. Over rough country where ascending and descending currents of air are encountered a plane frequently loses altitude while in a climbing position, and regains it with the nose down in a glide. This is confusing but not dangerous.

Follow carefully the route you have marked out on the map. Railroad tracks or strongly identified roads will help you to keep a straight course from one landmark to the next. If you lose sight of the object toward which you are heading, do not wander about aimlessly in search of it. Go back to the last landmark and make a fresh start.

If there is any doubt as to the identity of a landmark, e.g., if you do not know whether a lake below you or beyond it is the one you have marked on the map, you can usually correct the difficulty by calculating the amount of time it should have taken you to fly from the last landmark to the next and doubtful one. As an example, suppose that the distance between two preceding landmarks was 12½ ground miles, according to the scale of the map, and you flew the distance in a quarter of an hour. Then, if the distance, as measured on the map, is 25 miles between the last and the doubtful landmark, it should take you approximately half an hour to fly from one to the other. If you have flown only 20 minutes the object farther ahead, and not the one you have just overtaken, must be the one you are looking for. This method of calculation is, of course, a crude one, and will be of little value if there is a material change in the direction or speed of the wind.

It is of assistance, in checking your ground speed, while in flight, to have your course on the map marked with 10-mile intervals. There should be a short pencil mark across the course every 10 miles, and a diamond-shaped mark at every 50-mile interval. This will enable you to check your ground speed.

But you must also be able to check your compass bearing. This is done by using certain simple tables (the table shown in Figure 175) in conjunction with the course line on the map. This will enable you to fly with a considerable degree of accuracy. It should be remembered, however, that there is no such thing as a "constant compass course". The course, as corrected above, will

be good only as long as there is no change in the direction or velocity of the wind.

The Danger of Getting Lost. If you get so far off your course that there are no longer any landmarks in sight, the best

Miles Flown	Miles Off Course to the *Right*						
	2	4	6	8	10	15	20
25	− 5°	− 9°	− 13°	.....	.....	.....	.....
50	− 2°	− 4°	− 7°	− 9°	− 11°	.....	.....
75	− 2°	− 3°	− 5°	− 6°	− 8°	− 11°	.....
100	− 1°	− 2°	− 3°	− 4°	− 6°	− 8°	− 11°
200	.....	− 1°	− 2°	− 2°	− 3°	− 4°	− 6°

Subtract above correction from Compass Course.

Miles Flown	Miles Off Course to the *Left*						
	2	4	6	8	10	15	20
25	+ 5°	+ 9°	+ 13°	.....	.....	.....	.....
50	+ 2°	+ 4°	+ 7°	+ 9°	+ 11°	.....	.....
75	+ 2°	+ 3°	+ 5°	+ 6°	+ 8°	+ 11°	.....
100	+ 1°	+ 2°	+ 3°	+ 4°	+ 6°	+ 8°	+ 11°
200	.....	+ 1°	+ 2°	+ 2°	+ 3°	+ 4°	+ 6°

Add above correction to Compass Course.

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FIG. 175. TABLES FOR CHECKING COMPASS COURSE

These tables are used in conjunction with mile scale on course line.

Example: If, after flying 50 miles by the compass course, the landmarks indicate that the plane is 6 miles off course to the right, note the correction indicated in above table (−7°) and subtract it from the original Compass Course. This gives the corrected compass course to be followed.

plan, usually, is to continue for a little while in the general direction of the next landmark. When you have flown so long that you should have overtaken it, if it is still not in view, you must try some other plan. If the region over which you are flying

is markedly distinguished in any way, you may be able to locate it on the map, and so get back on your original course. It may be necessary to land and inquire your whereabouts, if there is any place to ground the plane and any people of whom to inquire.

In fog flying it is an easy matter for those not thoroughly familiar with the magnetic compass and turn indicator to lose all sense of direction; the compass may even oscillate until it begins to turn slowly like a top.

Even if the sense of direction is not lost, it is not always easy to identify one's position on coming out of a fog. At such times a properly air-marked city is most welcome. But, in the absence of such air marking, nearly every city or town has its own distinctive marking.

A city may be located where two main railroads cross; this is a mark that will not be duplicated within a radius of many miles, and even the angle of their crossing is faithfully pictured on the map.

Another city lies in the "V" where two rivers meet; another is just beyond the intersection of one of those rivers with a railroad.

County seats are marked on the map with a circle and dot symbol. In flight, the distinctive architecture of the courthouse—usually a dome—is an easily recognized landmark. As a final resort, if no roof markings are available, the name of the town can be read from the sign on the railroad station.

Even the county lines and township lines may prove of value, as minor highways and fences generally trend with these lines, taking their direction from them.

Having identified one's position, if still uncertain of the direction, a straight course may be steered in any direction until a second ground position can be identified. The course followed between these two points may then be determined by reference to the map, and a new course set for the destination.

Getting lost in the fog is dangerous. The most efficacious remedy for this evil is never to fly in fog. If a bank of fog does overtake you, land immediately. There is always a possibility that the fog is at some altitude and that you will be able to pass through the cloudy bank and see the ground clearly enough to

make a landing. At any rate, as soon as fog sets in, get to the ground before it becomes any denser.

Landings. It is well to plan to end a cross-country flight in a city or town which is equipped with a flying field. In such a case, you need only make a circuit of the grounds to discover the best line of approach, before landing, in the same manner as you would in your home field. However, if you are obliged, either by some emergency other than engine failure or because you have reached your destination, to land in a field which has not been prepared for flying purposes, you should follow the same procedure in choosing the field and planning the approach as though the landing were forced. It will be possible in this case to fly over the field at a low altitude, or to "drag" it, in order to inspect it before landing.

Use of the Compass. The method of navigation described above is the only one for which the ordinary person will have a great deal of use. You should, nevertheless, be acquainted with the plotting and following of courses by compass, since the principles involved are often used in cross-country and night flights, and in flights across water. In order to set a compass course, a line should be drawn on the map to indicate the route. This route will be a straight line across water and across level country; curves must be made in it if a straight course would pass over the dangerous or rough terrain. Suppose the course marked on the map goes due east. Then the compass must be set so that a due east course can be maintained.

The compass—besides being marked with the points of the compass—is also graduated to show the 360 degrees of a circle, with 0 degrees at north, 90 degrees at east, 180 degrees at south, and 270 degrees at west. It would be natural to suppose that, in order to fly due east, the compass should be set at 90 degrees. As a matter of fact, however, such a setting of the compass would probably carry you a considerable distance away from your destination. This error would be due to two factors which cause a difference to exist between compass direction and actual direction. These two factors are *variation* and *deviation*. (See Figure 176.)

Variation is due to the fact that the magnetic poles of the earth do not exactly coincide with its geographic poles. The compass points to the magnetic north instead of the true north, as it is shown on the map. The amount of variation differs in different parts of the world. The amount of variation in different regions is shown on all navigation maps and charts. (See Figure 177.)

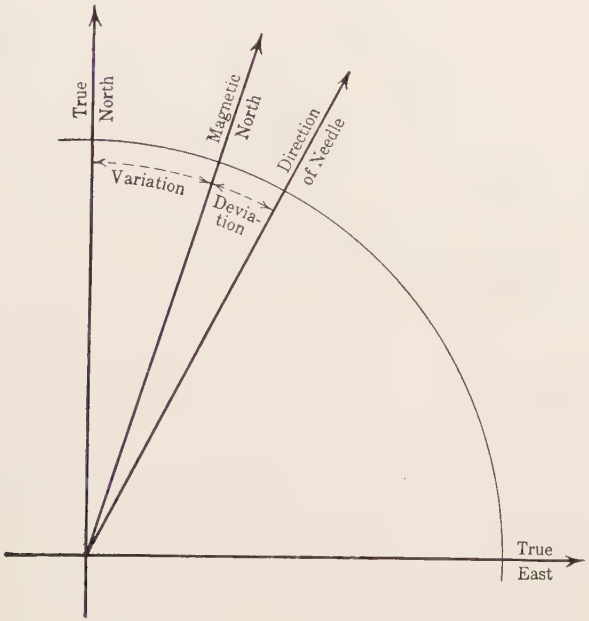

FIG. 176. VARIATION AND DEVIATION

Variation is the difference in degrees between the true North and the magnetic north. Deviation is the difference in degrees between the magnetic north and the compass needle. Variation may be either to the east, as above, or west. Deviation, in the same way, may be either east of the magnetic north, as above, or west of the magnetic north.

Deviation is caused by magnetic disturbances induced by the iron and steel parts of the ship itself, and by the electrical currents set up by the ignition system. Deviation is measured by the number of degrees east or west by which the compass deviates from the magnetic north, that is, from the magnetic meridian.

The deviation of every plane must be determined separately, exactly as is the case with a vessel. To do this, a special test of the compass is made, in which the readings of the compass are compared with the magnetic meridian. A chart is then made up showing the resultant differences, that is, the deviation of the compass. This has to be done for various directions in which the plane may be heading. The process is known as "compensating the compass." (See Figure 178.) Tools, cargo, and so forth,

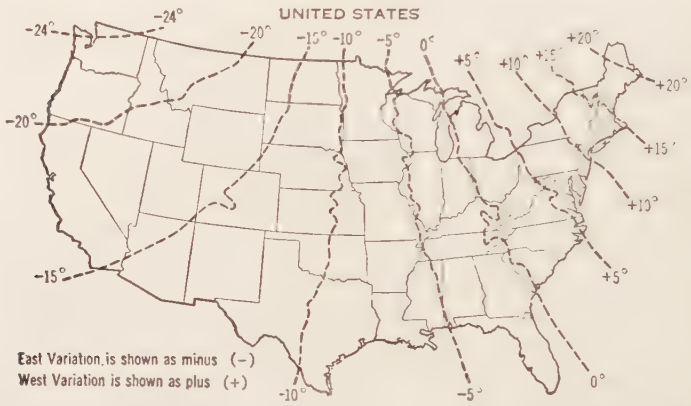

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FIG. 177. MAGNETIC VARIATION FOR THE UNITED STATES

Lines of equal magnetic variation are indicated on maps for navigation purposes, their value being given in the border, followed by plus or minus signs. A line of magnetic variation marked 4°+ indicates that anywhere along that line the compass points 4° west of true north, and 4° must be added to the true course to find the magnetic course. If the line is marked 15°—, the compass points 15° east of true north, and 15° must be subtracted from the true course.

near the compass, frequently affect its readings. Tools, therefore, should be kept in their places at all times.

By means of the chart, the *deviation* between the compass reading and the magnetic course can be allowed for, in precisely the same way as the *variation* between the true and the magnetic course is allowed for.

Both variation and deviation are considered positive (plus) if to the east, and negative (minus) if to the west. These differ-

ences (errors) are added to or subtracted from the compass reading in order to obtain the true course.

FIG. 178. COMPENSATING THE COMPASS

To correct errors in the compass for deviation, it is necessary to "swing the ship" in various known directions, and to make up a deviation card. This shows how the ship is swung. Notice the turntable; also, the concentric circles. (The device is called a compass "rose.")

Allowance for Wind. Knowing the correct angles and distances, it is possible to lay out any course on a map. Corrections for compass error must, of course, be made, as just described. Distances traveled can be computed by means of the air-speed meter. If the plane is traveling at the rate of 100 miles per hour, you know that it will take you half an hour to cover 50 miles.

This is known as *dead reckoning,* and does not take into consideration the effect of the wind. But the effect must be allowed for, just as the captain of a vessel must allow for leeway, that is, for those forces which affect his course, aside from the distance shown by his log. The sideways drift of a plane can be measured by means of a *drift indicator.*

With a drift indicator, the angle of wind drift may be read directly, and the ground speed being made good may be quickly determined by noting the time it takes for an object on the ground to pass along the drift wire of the instrument. Many

pilots become expert at estimating drift without any indicator, and learn by experience to make the necessary allowance.

To find out how far an airplane will travel in a given length of time, where there is a given wind velocity, follow the procedure in Figure 179. This is a simple problem in triangulation.

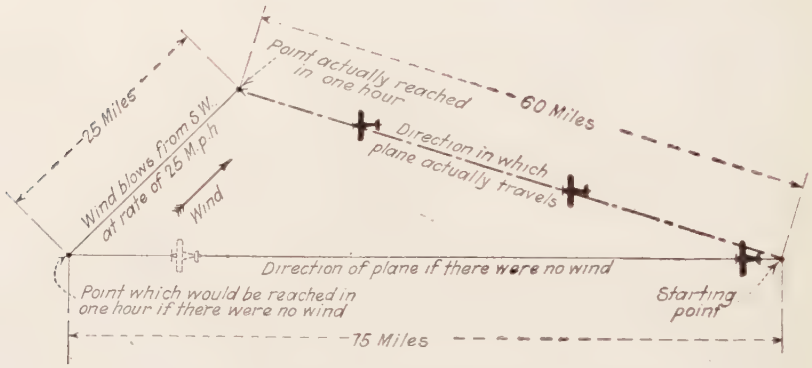
Point actually reached in one hour
60 Miles
25 Miles
Wind blows from S.W. at rate of 25 M.p.h.
Wind
Direction in which plane actually travels
Direction of plane if there were no wind
Point which would be reached in one hour if there were no wind
Starting point
75 Miles

FIG. 179. EFFECT OF THE WIND ON A COURSE

To determine the point which will be reached in an hour by a plane heading due west at 75 miles per hour, when there is a 25-mile wind blowing from the southwest, lay off on a due west course the point which would have been reached if there had been no wind. From that point, lay off the wind component—twenty-five miles on the line in which the wind is blowing. This will determine the position which will actually be reached at the end of the hour. The actual mileage covered can then be found, either by plotting on a chart or by mathematical computation.

One leg of the triangle represents the direction and distance of the plane as it would travel if there *were* no wind. The second leg represents the direction of the wind, and the distance which *it* would travel in the given interval of time. The third leg (resultant) shows the direction and distance which the ship will actually travel. This direction (bearing) and distance from the starting point may be calculated by means of simple tables prepared for this purpose. Or, by laying the triangle out on paper, to scale, a sufficiently accurate result can be directly taken off the drawing, by the use of a scale rule and a protractor.

Laying Out a Course. Once you understand how the wind affects the course of the plane, and how to determine accurately the position the plane will be in at the end of a given interval of time, the problem of laying out an actual course is simple. A map is needed, a straight edge or parallel rule, a protractor, and a pair of dividers. The method used is shown in Figure 180. It is much

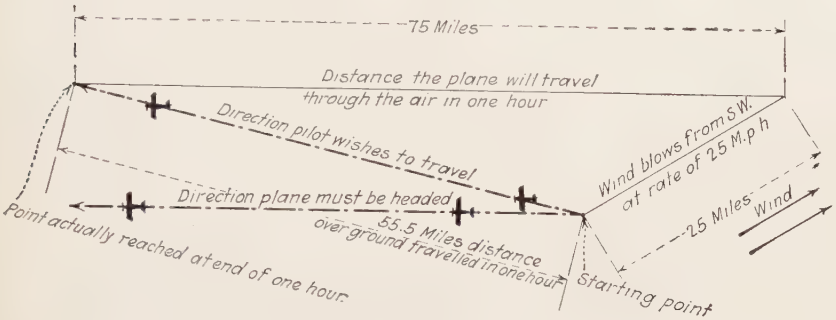
75 Miles
Distance the plane will travel through the air in one hour
Direction pilot wishes to travel
Direction plane must be headed
55.5 Miles distance over ground travelled in one hour
Point actually reached at end of one hour
Wind blows from S.W. at rate of 25 M.p.h
25 Miles
Wind
Starting point

FIG. 180. LAYING OUT A COURSE

The pilot wishes to travel due west from the starting point, all conditions being the same as in the previous figure. He first lays out this course on his chart—simply draws a line due west from the starting point. Second, beginning, again, at the starting point, he lays off the wind component, that is, a line showing the direction and distance of the wind, during an hour's interval (25 miles, from the southwest). Taking as a center the point at the extremity of the line thus obtained, and with a radius equal to the distance through the air which his plane will travel in one hour, he determines where this radius will cut his due west course. This will enable him to draw the third, and longest, leg of the triangle. A line parallel to this leg, but drawn from the starting point, will show him the direction in which he must head his plane in order to travel a due-west course. The third leg of the triangle will also show, by the point at which it cuts the due-west course, the distance which will be covered at the end of the hour.

the same as before, except that you lay out the wind component from the starting point. This is the first leg of the triangle, showing both direction and distance. With the outer extremity of this line as a center, and with a radius equal to the number of miles which the plane will travel through the air in an hour, you "cut" your original course. This point of intersection is found by using an ordinary pair of compasses. A line drawn parallel to this radius

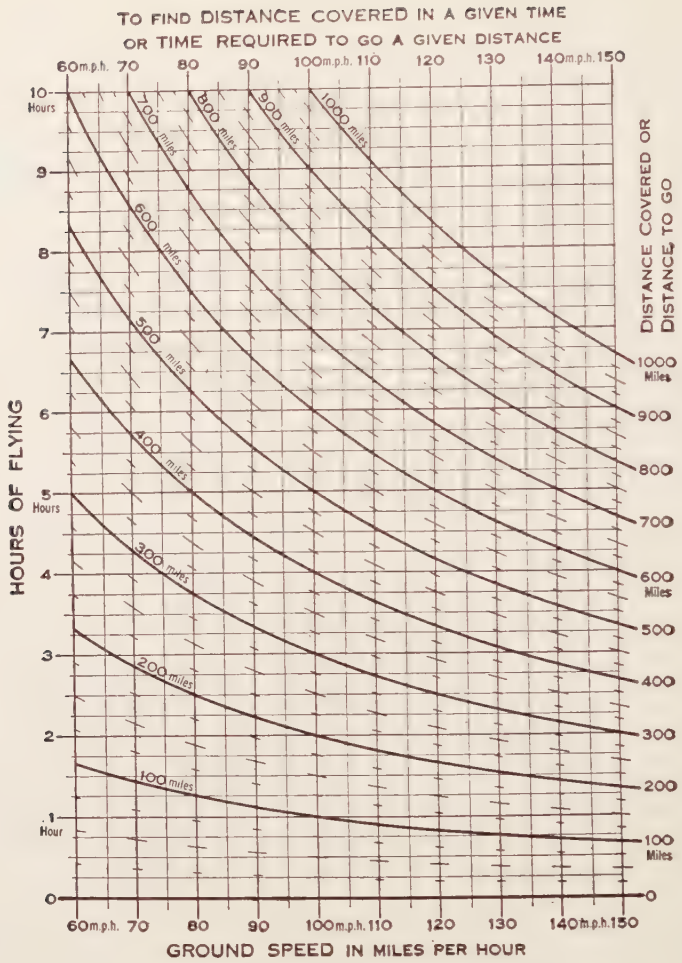

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FIG. 181. TIME AND DISTANCE CHART

To find time required to go a given distance. With the distance, scaled from the map, and the ground speed determined, as previously described, the number of hours required to make the trip may be quickly found. For example, to find the time required to go 450 miles at a ground speed of 90 miles per hour, read up to the 90 m.p.h. ground speed line to its intersection with the 450 mile distance curve. Then read across to the left and find the number of hours of flying, indicated by this intersection.

(Allowance must be made for any change in wind or weather conditions during flight.)

To find distance covered in given time (for dead reckoning in blind flying). With ground speed determined before taking off, or by check

line, but originating at the starting point, gives the bearing, that is, the direction in which the plane must be headed in order to allow for the wind. It is also possible to determine the number of miles over the ground which will have been flown at the end of the hour.

In the above illustration, one hour has been taken for convenience; but the same principle holds true, no matter how long the interval of time, provided the conditions remain unchanged. By the method shown in Figure 180, the distance over the ground which can be traveled per hour is known, and also the direction in which the plane must be headed, so that it is a simple calculation to determine how long it will take to arrive at a given destination. One method of determining distance covered in a given time (or the time required to go a certain distance) is shown in Figure 181.

It should be remembered that allowance has to be made, in all such computations, for variation and deviation. Also, it should be remembered that the wind will vary in velocity and direction, hour by hour and at different altitudes. The result is that the entire process of navigating becomes extremely troublesome. The whole process of air navigation in its practical application by experienced flyers is a combination of steering by compass and constant checking of the course by landmarks which are readily identifiable or may be made out by consultation with the map. In general, it may be said that to attempt cross-country flying either without a compass or without constantly checking your course over the ground is equally foolish. There are special cases which warrant exceptions, but on the whole this is the safest rule to follow. Although it is important for the student to acquaint himself with the elements of this science, he need not be surprised if he finds it is difficult to translate the theoretical into the practical when he is actually trying to reach his destination.

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during any "visible" part of the flight, the distance covered may be found by noting the distance curve which passes through the intersection of the ground speed line and the hours covered will be 385 miles (this is estimated from its position less than half way between the 375 mile mark and the 400 mile curve). The positions, so determined, should be noted on the map from time to time. The approximate location of the plane, obtained by this method, will greatly aid in identifying position upon coming into clear weather again.

A wind correction rose may be used in laying out courses. Figure 182 shows such a rose. Figure 183 is an example of a navigational problem.

Night Flying. Flying by night is much more difficult than flying by day. On a dark night, it is almost impossible to judge the height of the plane above the ground. The whole appearance

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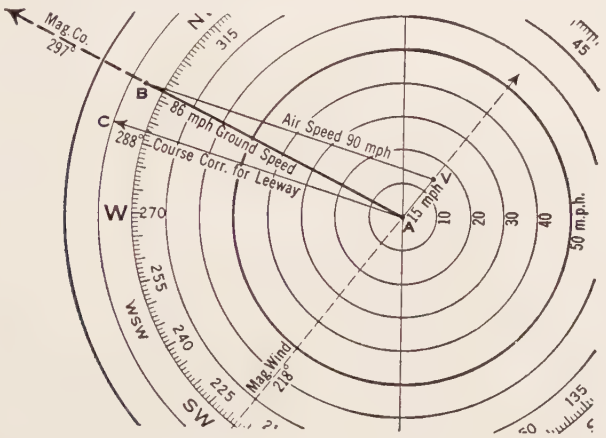
FIG. 182. COMPASS AND WIND CORRECTION ROSE

The "rose" is used to lay out a course, corrected for leeway, and to determine ground speed of the airplane when wind direction and velocity are known, as well as the magnetic course and the air speed. The data may be plotted lightly in pencil and erased after using.

of things is different, as may be judged from Figure 184. Landing fields on which planes land regularly at night are equipped with flood lights. These throw a blaze of illumination across the field. In such light, the landing may be made easily, as soon as

the pilot has had a little practice. Landing in unlighted fields must be made with far greater care. On dark nights, it is a good plan to drop a small flare, attached to a parachute, above an unlighted field, to light you on your way.

To many, night flying is the pleasantest of any. The air is usually smooth and still. If there is a lighted airway to follow,



Rand McNally & Company

FIG. 183. GRAPHIC WIND CORRECTION AND GROUND SPEED

The air speed of the ship is 90 miles per hour.

Let A, at the center, represent the starting point, and let the circles denote intervals of 10 m.p.h.

Draw line representing the magnetic course from A, through 297°, and beyond.

Plot Mag. Wind Direction from 218°, through A, and well beyond.

Lay off the Wind Velocity, 15 m.p.h., on this line from A to the Leeward (away from the wind).

Plot the Air Speed of the Plane at 90 m.p.h. from V to meet the Magnetic Course Line. (Scale 90 m.p.h. from across center of "Rose" with edge of paper and pencil.)

Plot line AC, parallel to line VB.

The Bearing of line AC is 288°, and represents the Magnetic Course corrected for Leeway.

The scaled value of AB is 86 m.p.h., which gives the Ground Speed. This line also represents the Course Made Good.

travel is easier than on a city street. Night flying, particularly by moonlight, is a most exhilarating experience.

* * * * * * * * *

Cross-country flying is, to the newly initiated, a great pleasure. It is a "sporting proposition." It requires alertness. It provides the enjoyment of unfamiliar scenery. When several long flights have been made, the handling of the plane becomes simple. The opportunities for travel, exploration, and adventure, which are now opened up to the flyer, are almost limitless.

FIG. 184. SHIP EQUIPPED FOR NIGHT FLYING

This photograph of a tri-motored Boeing Transport plane was made just after a night flight from Oakland, California, to Salt Lake City, Utah. It gives some indication of how differently a ship looks at night.

QUESTIONS FOR REVIEW

1. What is the use of the map in cross-country flying? Discuss at length.
2. Obtain an air map. What features are shown? How does it differ from a railroad map? An automobile map?
3. Interview a pilot as to the value of strip maps.
4. What weather conditions are suitable for cross-country flying? How can these be forecast?
5. Get a student to describe his first cross-country flight. What errors, if any, does he appear to have made?
6. Write your ideas as to what to do when lost.
7. Describe the use of the compass in making cross-country flights.
8. Define variation and deviation. What allowances must be made for them?

9. Lay out a course for a flight which you might actually make. Make allowances for a moderate cross wind.

10. What do you consider the chief value of learning to do cross-country flying?

SUGGESTIONS FOR READING ON CROSS-COUNTRY FLYING AND NAVIGATION

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Yancey, Lewis A., *Aerial Navigation and Meteorology,* chaps. I to VIII. Henley.

GLOSSARY

The figures appearing after the various terms refer to pages upon which the reader may find additional information.

GLOSSARY

Acrobatics, 58, 249, 262
Intentional maneuvers not necessary to air navigation.

Aerodynamics, 81
Study of air under the action of force, such as the mechanical effect of aircraft upon it and *vice versa*.

Ailerons, 100, 101, 120
Portions of the controlling surface of an airplane, extending for all or part of the wing spread and hinged or pivoted to the rear section of the wings. On a biplane they may be located on either the upper or the lower wing, or on both. By moving the stick transversely, one aileron is lowered and the other elevated. This tilts the airplane in the desired direction. If the stick is moved to the left, the right aileron is depressed and the left aileron elevated, the result being a bank to the left, since the lift on the left side of the wing is decreased.

Airfoil, 8
Any surface designed to produce a useful dynamic reaction when projected through the air.

Air marking, 315
A mark, distinctly visible from an airplane, by which an unfamiliar pilot may recognize a town or city; usually the name of the community is painted on a rooftop.

Air-speed, 138
Rate of progress of a plane relative to the air, as contrasted with ground speed, or rate of progress relative to the ground. The direction and velocity of the wind have practically no effect upon the air-speed.

Air-speed meter, 253, 319
Instrument which measures the speed of the plane through the air.

Altimeter, 137
A form of aneroid barometer which indicates the altitude at which an aircraft is flying. The dial may be adjusted for changes in barometric pressure, and should be set at zero before each flight.

Amphibian, 19
An airplane equipped with two sets of landing-gear, one of which allows the plane to land on or take off from the water, and the other of which allows it to land on or take off from the ground. This landing-gear is usually adjustable from the cockpit during flight.

Anemometer, 107
An instrument for measuring the speed of the wind.

Angle of attack, 86
Acute angle formed by the cord of the airfoil and the direction of the airflow, or relative wind. The maximum angle of attack is the greatest angle at which horizontal flight may be maintained. The optimum angle of attack is that at which the ratio between the resistance of the air and the lift of the plane is most efficient.

Angle, critical, 91
Angle of attack at which streamline flow ceases to be smooth, and tends to break down into eddies and vortices. Called also burble point.

Angle, dihedral, 39, 175, 98
When the wings of a plane are slanted upward toward the wing tips, the angle between them is known as the dihedral angle.

Angle, gliding, 39, 208, 209, 211
Acute angle formed by the path of the gliding plane and the horizontal. The minimum gliding angle is the

least angle at which a plane can descend, the engine being throttled.

Angle of incidence, 90
Angle between cord and line of thrust, or line of the propeller shaft.

Anti-cyclone, 109
A high-pressure area, usually presaging fair weather.

Aspect ratio, 86, 88
Ratio of span to chord.
Take distance from tip to tip and divide by chord.
Aspect ratio of propeller blade is equal to one-half diameter divided by maximum width.

Axes of plane, 97
"X" axis (longitudinal axis) is line from nose to tail.
"Y" axis (lateral axis) is line from wing tip to wing tip.
"Z" axis (vertical axis) is line drawn vertical and perpendicular to the other two.

Balanced surface, 99
A control surface, part of which extends forward of the line drawn through the hinges.

Bank, 76, 252
To incline an airplane laterally. When the right wing is down it is known as a right bank, and when the left wing is down as a left bank. Banking is controlled by the action of the ailerons. When turning, the plane must be banked to correspond to the sharpness of turn. Not enough bank causes skidding; too much bank causes side slipping.

Barograph, 31
A self-registering barometer which, by recording changes in atmospheric pressure, indicates the altitude of flight. A form of altimeter used when it is necessary to keep a record of the altitude.

Biplane, 13, 159
An airplane with two wing surfaces. It is easily maneuvered as compared with other types of planes. It has the further advantage of high strength and comparatively narrow span.

Blind flying, 324
Flying without reference to any visible object on the earth or in the sky and relying solely upon instruments to guide the plane, as in a dense fog.

Body, 26, 85
See Fuselage.

Boss, propeller, 94
The boss refers to the hub of the propeller.

Burble point, 90, 92
See Critical angle.

Camber, 88
The degree of curve in an air-foil surface, measured by the ratio of the departure of the curve from the chord to the length of the chord.

Ceiling, 114
In popular terminology refers to height of clouds, and the "ceiling" is the maximum altitude at which the pilot can see the ground as he flies.

Ceiling, absolute
The maximum altitude which a given plane can attain above sea-level.

Ceiling, service
The altitude at which a given plane ceases to be able to rise at a rate of at least 100 feet per minute.

Center of gravity, 98
The point of static balance. If the airplane were supported at the exact center of gravity, it would not tend to revolve about that point, but would remain poised.

Center of pressure, 87, 97
Point where line of lift intersects the chord.

Chandelle, 223, 225
A sudden, steep, climbing turn, executed near the ground.

Chart, Time and Distance, 324
A chart, for easy reference, showing the distance covered in any given length of time at any given speed, or *vice versa*.

Chord, of a wing, 86
The straight line joining the leading and trailing edges of the wing.

Climb, 200
Gaining of altitude by a plane. The rate of climb is measured by the number of feet in altitude gained per minute.

Cockpit, 68, 69
Open space in body of plane for accommodation of pilot and passengers. An enclosed cockpit is known as a cabin.

Compass, compensating, 318, 319
Compensating a compass is usually done by placing small magnets in the mounting, to offset the effect of local influences such as the motor, so that the compass will indicate as nearly as possible the heading of the ship. The small differences not corrected by compensation are noted on a card for the pilot's easy reference.

Compass, induction, 142, 143
A compass the action of which depends upon a current generated by revolving a coil. Since the coil is within the earth's magnetic field the current generated depends upon the position of the coil in relation to north and south.

Compass rose, 323, 324, 325
A circular chart (bearing a faint resemblance to a star or rose) used for convenience in plotting a course.

Control surfaces, 124
Ailerons, rudder, and elevators, or any similar surface which by reaction upon the air stream will deflect the plane from its course.

Controls, 124
Term applied to cover the mechanisms which affect the movement of the plane and which are governed by the stick, rudder bar, or foot bar, engine throttle, stabilizer, brakes, etc.

Cowling, 152
The housing around the engine. In a water-cooled engine the cowling forms the nose of the plane.

Crabbing, 172
Making allowance for a cross wind by heading the plane into the wind slightly.

Crack-ups, 9
Any accident resulting in damage, as "spinning in" or bad landing.

Crash, 56, 77, 242
The wrecking of an airplane. A ground crash occurs while taxying; an air crash results from a fall from the air.

Cruising speed, 201
Normal and economical speed in level flight.

Cyclone, 109
An area of lowered barometric pressure where the air rushes inward toward the center of the area and upward in a counter-clockwise spiral.

Deviation, 317
Difference between the compass needle and the magnetic north. Such differences are caused by local interference, such as engine.

Dive, 209, 256
A sharp descent causing a speed greater than the normal speed in horizontal flight.

Downwash,
The air deflected downward by the wing in its passage through the air is known as downwash.

Drag, 86
Resistance encountered by any body as it passes through the air.

Drift, 139
As a verb, means to be carried off the direct course by an air current. As a noun, the amount of divergence caused by air current.

Drift, angle of, 320
Angular difference between direction in which the ship heads and direction of the true path over surface of earth.

Dual system of controls, 68
Two complete sets of primary controls, stick, rudder bar, and throttle,

so mounted that either set operates the plane completely, for convenience of student and instructor.

Duralamin, 162
Alloy of copper and aluminum often used in airplane construction, because of its lightness and strength.

Elevator, 28, 32, 94, 120, 170, 185, 216
Two movable airfoils, in the form of horizontal rudders, usually hinged to the stabilizer, which control the up-and-down movements of the plane. Operated by the backward and forward motion of the stick.

Elevator-turn, 177
When the angle of bank is more than forty-five degrees the functions of elevator and rudder become reversed, the elevator acting as rudder, and the rudder as an elevator.

Endurance,
The maximum length of time which a plane can stay in the air before the necessity of refueling arises. A plane's endurance is calculated in accordance with its normal speed, the altitude at which it is flying, and its average fuel consumption.

Fairing, 84
Material which is added to struts or wires to produce streamline form, but which does not in general produce added strength.

"Feel," 30, 32, 51, 78, 128, 130, 144
The ability to sense exactly what is taking place, without special exertion or use of instruments, but merely by the sound of the ship and the way the controls respond to the pilot's movements.

Figure eights, 41, 278
A maneuver wherein the plane's path of flight is similar to a horizontal figure 8, and done accurately over specified points.

Fin, 28, 98, 169
A fixed vertical surface, sometimes called vertical stabilizer, located at the rear end of fuselage, which serves to give the plane directional stability, much as feathers keep an arrow straight in flight.

Fire wall, 28
A bulkhead which isolates the engine compartment from the rest of the structure and thus reduces fire risk.

Flight,
A plane is in flight when its speed is sufficient to support it in the air. Flight may be made with the use of the engine, or in a glide with the engine throttled. The term "cross-country flight" is used to cover any flight which takes the plane away from a regular landing field. Flight path is the track made by the center of gravity of the plane in reference to the earth.

Float seaplane, 16
An airplane equipped with single or double pontoons so that it can take off from and land on the water.

Flying boat, 17, 18
An airplane of which the fuselage is used as a float upon which the plane can take off from and land on the water.

Formation flying, 260, 293
A practice of flying several planes in a definitely arranged group, as birds fly, in a "V" or otherwise.

Freeze to controls, 124
Gripping of the controls by the student in such a way as to interfere with instructor's operation of them.

Fuselage, 26, 84, 100, 168
Term applied to the body of the plane, containing motor, passengers, and cargo. It includes cowling and covering, but excludes wing and tail surfaces, which are attached to the fuselage. Single-engined planes usually have power plant mounted in the body or fuselage. When the power plant is not installed in the body, it is called the *nacelle*.

Gap, 101
The distance between the wings of a biplane.

Gear, reduction, 150
A set of gears connecting the engine crankshaft to the propeller so that the propeller revolves more slowly than the engine.

Glide, 37, 38, 77, 127
Loss of altitude with engine throttled down to a point insufficient to maintain horizontal flight, the force of gravity being substituted for the propeller thrust. The normal rate of descent is about one vertical foot for every seven horizontal. When the angle of glide is sufficiently increased, it becomes a dive.

Glider, 277
A motorless plane capable of gliding flight.

Ground loop, 36, 41, 186
If a plane is turned too sharply when taxying, the center of weight, which is behind the wheels, tends to make the turn even sharper, the result often being a ground crash. A ground loop may be made through freezing of a wheel, or lack of control in a cross wind.

Ground speed, 320, 326
Actual speed over the ground, irrespective of air speed.

Ground-speed meter,
An instrument by which sights are taken upon the earth and the apparent motion of the earth timed so that its speed relative to the plane may be estimated.

Gun, 210, 215, 273
General term indicating throttle and its effect.
To "give her the gun" is to open the throttle.
To "cut the gun" is to close the throttle.
"Full gun" is throttle wide open. "Shot of the gun" is a short burst of power.

Hands-off,
Flying with hands off the controls.

Helicopter, 9
A machine with rotating wings or propeller which pulls it directly upward and which does not depend upon its forward motion to sustain it as the airplane does.

Horns, 29, 124
Short levers on the ailerons, rudder, and elevator, to which the control leads are attached.

Hot spot, 157
An area of hot metal over which the carburetted mixture passes before entering the cylinders, so that the fuel will be thoroughly vaporized and warmed.

Hydroplane, 288, 289
A boat which travels on top of the water and which does not displace any considerable volume of water but derives its support by planing or skimming over the surface, like a surfboard or aquaplane.

Inclinometer, 138
An instrument for measuring the angular attitude of a plane to the horizontal, and which may indicate either roll or pitch.

Indicators, 31, 137, 139
Indicators are of various types and for various purposes, as bank and turn, air speed, angle of attack, pitch, etc., and indicate conditions affecting the plane.

"Joy stick," 122
The rod or column by which the pilot operates the ailerons and elevators. The "stick."

Landing, 25, 56, 115
Term used to cover maneuvers of plane from beginning of glide to complete stop on the ground.

Landing, cross wind, 269, 271
Landing so that the plane is drifting sidewise over the ground until the moment before the plane actually touches.

Landing, dead stick, 218, 268
Landing with dead motor. Since the propeller exerts no thrust, the gliding angle must be steeper.

Landing, fish-tail, 219
When altitude is lost by skidding alternately to the right and left. Prevents overshooting the field.

Landing, forced, 218, 264, 268
When, through engine trouble, or otherwise, an immediate landing is made necessary.

Landing gear, 15, 25, 27, 100, 197
Understructure of plane supporting it when on the surface of land or water. Landing gear may be in the form of boat, float, skid, wheel, or ski. Amphibian planes combine boat or float with wheels.

Landing, "pancake," 217, 219
Landing so that the plane stalls slightly above ground and suddenly drops heavily and out of control.

Landing, "spot," 264
Landing on, or as near as possible to, a designated spot on the ground.

Landing T, 206
A T-shaped object, large enough to be seen from a distance, which indicates the direction of wind.

Landing, tail-high, 218, 293
Landing so that the wheels touch ground before the tail.

Landing, three-point, 216, 218
When wheels and tail skid touch ground simultaneously. This is the perfect form of landing.

Landplane, 9, 10
An airplane equipped with wheels, skids, or skis, so that landings and take-offs may be made on solid ground.

Leveling off, 37, 193, 197, 212
Term used in landing. Gliding angle is gradually decreased until plane attains level flight just above the surface of ground. Also refers to "leveling off" into level flight after a climb.

Lift, 38, 89
Vertical support exerted by the air on the wing surfaces of the airplane when in flight.

Load, 96
The burden or weight carried in the air. Useful load includes crew, passengers, baggage, oil, and gasoline, and all items loaded in the plane. Full load is the weight of the plane empty plus its useful load. The pay load is the portion of the useful load which supplies revenue, such as passengers, express packages, or mail.

Load, dynamic, 96
A stress due to rapid change of direction and, or, velocity; as flattening out from a dive.

Load face, 94
The flat face of a propeller blade.

Load factor, 96
Ratio of breaking stress to stress during normal level flight.

Loading, power, 96
Total weight of plane divided by normal power of engine.

Loading, wing
Total weight of plane divided by area of wings.

Longeron, 25, 26
Parts of the framing of a plane extending from nose to tail, as opposed to the struts which run horizontally or vertically between the longerons. Formerly made of wood, but now largely of steel tubing.

Low, 109
A "low" is an area where the barometric pressure is lower than normal. Usually several hundred miles in diameter.

Monoplane, 9, 13, 92
An airplane with a single wing surface. It is comparatively inexpensive to construct, and provides great lifting power.

Nacelle, 127, 128, 168, 245, 297
Inclosed section of the plane, carrying passengers or power plant, usually shorter than fuselage, and does not carry tail unit. When motors are mounted on wings, housings which inclose them are called motor nacelles.

Nose down, to, 240
To go into a glide.
Nose-heaviness, 128, 213, 291
The tendency of the nose to drop into a glide.

Ornithopter, 9
A machine with flapping wings, designed to fly like a bird.
Orthagonal,
When one wing is set directly over the other *i.e.*, without stagger.
Overhang,
Sometimes used to mean the distance from outer strut attachment to wing tip, but more commonly means half the difference in span between the two wings. If the upper wing has the larger span, the overhang is known as positive.
Over-revving,
Term applied to racing the motor faster than it should be run.
Overshoot, 265
To come into the field too high so that the landing is impractical or impossible.

Pack, parachute, 300
The container for the parachute.
Parachute, 297, 305
An umbrella-shaped device, made of cloth, which retards the descent of a falling body.
gores of, 279
The individual pieces of cloth of which the parachute is composed.
harness, 300
A set of straps which are fastened about the body of the person so as to distribute the strain and prevent him from being detached from the parachute.
Pilot, chute, 300, 303
A small umbrella-shaped affair, with wire springs in it, so that it projects itself away from the wearer when released and, being caught by the air, drags the main chute from the pack.
Pitch, 94
Term used to define distance a propeller would travel in one complete revolution if it were to screw its way through a solid. Also used with reference to pitching, as below.
Pitching, 97
Falling or rising of the nose.
Pitot tube, 138
A tube with an open end which encounters the air head on. The resulting pressure is measured by a pressure gauge connected to the tube.
Pitot-static tube, 138
Pitot tube combined with tube which gives static pressure so that the instrument measures the difference.
Priming system, 189
A device for injecting fuel or combustible mixture into the engine to facilitate starting.
Propeller, 93, 94, 100, 183
The air-screw which pulls the plane through the air. Sometimes called "prop."
Propeller hub, 94
Metal fitting used for mounting propeller on shaft.
Propeller interference, 95
Change in torque and thrust caused by effect of some part of the plane, such as the engine, on the airflow in the slipstream.
Propeller pitch, 94
The effective pitch of a propeller is the distance which the propeller travels during one revolution. Some propellers have blades which may be set to the desired pitch.
Propeller thrust, 163
See Thrust
Propeller track
Circle described by any point on the propeller during one revolution.
Propeller wash, 93
Air cone from the propeller thrust. *See* Slipstream
Pusher airplane, 5
An airplane of which the propeller revolves behind the wings.

Range
Distance which plane can fly under

normal conditions. Range at full speed means the maximum distance a plane can cover at full speed at sea-level. Range at economic speed is the maximum distance a plane can cover while flying at the most economical speed and altitude.

Resistance, 87, 89, 92, 94
Opposition offered by the air to the plane. Head resistance covers resistance of the air to the entire plane. Wing drag means the resistance to the wings alone. Parasite resistance is that offered by fuselage, wires, struts, etc.

"Reverse-control" flying, 180, 249, 281
Reverse-control flying is usually defined as any maneuver where the plane is banked forty-five degrees or more.

Righting moment, 98
A moment or force which tends to return the ship to its normal position whenever displaced.

Rip cord, 300, 304
A device consisting of a cord with a ring on the end, by which the parachute is released from its pack.

Roll, 97, 257
Rotation about fore-and-aft axis. Dropping or raising a wing.
Plane makes a complete turn on its back, and comes right side up again, while still maintaining its horizontal course. Used in stunt flying.

Rudder, 28, 68, 94, 98, 123, 126
One of the control surfaces, usually hinged to fin, which causes plane to turn right or left as the pilot moves the foot or rudder bar. When angle of bank is more than forty-five degrees it controls the altitude of the plane.

Rudder bar, 28, 66, 70, 123, 128
Bar or pedals on which pilot's feet rest. Pressure with the right foot turns the plane to the right.

Sailplane, 280
A term applied to the advanced type of glider built for soaring.

Seaplane, 9, 14, 16, 226
An airplane of which the landing structure consists of a boat or floats, so that landings and take-offs must be made on the water.

Sesquiplane, 19
A biplane of which the lower wing surface is considerably shorter than the upper wing surface.

Shock-absorber, 25
A device incorporated in the landing gear in such a way as to lessen the shock when the ship lands.

Shock cord, 278, 279, 283
A rope made up of rubber strands, used for a shock-absorbing device.

Shroud lines, 297, 299
The lines connecting the cloth of the parachute to the harness.

Side slip, 55, 251, 272
When a plane banks too much for a turn, the plane slides inward towards the lower wing. Side slipping is used to lose altitude without gaining speed, in landing.

Skid, 179, 256
The result of insufficient bank when turning, causing the ship to slide outward.

Slip, 95, 98
The difference in percentage between the distance which the propeller actually moves in one revolution and the distance it would move theoretically if there were nothing to hold it back. The faster the plane flies, the less the slip will be. The slip is greater during climbing than horizontal flight.

Slipstream, 95, 121, 138, 156, 159, 163
Sometimes called propeller wash. The cone of air resulting from the propeller thrust and driven astern.

Slotted-wing device, 93
A device for producing a slot or opening which allows a stream of air to pass from the lower surface to the top of the wing and thus increase the lift.

Solo, 20, 213, 245
Flying the plane alone.

Span, 86
The width of the airplane from wing tip to wing tip.

Speed, 37, 40, 95
Velocity of the plane through the air.
Economic speed is that at which fuel consumption is at a minimum compared with distance covered.
Flying speed is any speed at which safe flight may be maintained.
Ground speed is the velocity of a plane relative to the earth.
Landing speed is equivalent to minimum speed.
Maximum, 96—The highest speed that can be maintained in level flight.
Minimum or critical speed—is the lowest speed at level flight which a plane can maintain and still be under control. The angle of attack for minimum speed is high.
Stalling, 90—The speed at which the plane has not sufficient lift to sustain its weight.

Spin, 40, 42, 241
Form of stall in which the plane falls nose first, describing a corkscrew spiral, the tail of the airplane going around in a circle.

Spiral or spiral turn, 225, 226, 230
Form of glide in which plane makes a gradual descent in wide circles. A series of gliding turns.

Stability, 96, 97, 98, 99
Tendency of a plane to return to its original position whenever displaced.
Inherent—Tendency to return without assistance from the pilot of any device other than the fixed surfaces of the plane.
Longitudinal—Tendency to resist pitching.
Lateral—Tendency to resist rolling.
Directional—Tendency to resist yawing.

Stabilizer, 97, 98
A fixed horizontal airfoil, located at the rear of the fuselage, the function of which is to provide longitudinal stability. The elevators are hinged to it. It is usually adjustable.

Stagger, 101
Distance which one wing is set forward of the other.

Stall, 40, 55, 223, 232
The state of a plane when it has not sufficient air speed to support its flight.

Stall in, to, 264
In making a landing in a small field, the plane is put into a stall and, just before reaching the ground, the speed is accelerated by opening the throttle momentarily to avoid a pancake.

Stall off, to, 194, 195
When necessary to get plane into air as soon as possible, the angle of attack is increased enough to force the plane off the ground in an almost stalled condition.

Stick, 122
The stick, control stick, or joy stick, is the vertical lever which, moved backward and forward, controls the elevator and, moved sideways, controls the ailerons.

Streamline, 82, 156
The line of flow around an airfoil which follows a smooth unbroken path, without causing eddies or burbling.

Struts, 26, 84, 92
Members used to brace wings to fuselage. Vertical braces, or posts, between wings of a biplane. Rigid members forming the landing gear.

S-Turns, 180, 265, 287
A series of turns, alternately right and left, performed without straightening out between turns.

Supercharger, 160
A mechanical device for forcing more mixture into the engine than would normally be drawn in by the engine itself.

Swinging the ship, 319
Process of checking a compass, and compensating it, if necessary, by

putting the ship on a turntable and heading it in various directions, accurately determined, so that the compass reading may be compared with the ship's actual heading.

Tachometer, 31, 132, 201
Instrument which measures the revolutions per minute of the engine.

Tail group, 28, 184
The complete set of surfaces on the tail of the plane—rudder, elevators, fin, and stabilizer.

Tail-heavy, 126
If the plane goes into a climb when pressure on the stick is released, it is said to be tail heavy.

Tail skid, 25, 37, 100
Runner supporting the tail of a plane.

Tail slide,
Fall of a plane tail first, resulting usually from too steep a climb. *See also* Whip stall.

Take-off, 25, 189, 203
The act of maneuvering the plane from the ground into the air.

Taxying, 7, 15, 25, 36
Movement of plane over the ground under its own power. Used merely to move the plane from one place to another on the ground, and not as part of the take-off or landing.

Thrust, 90, 94, 163
Pull of the propeller measured in pounds.

Tipping, propeller,
Thin metal applied to the wooden propeller's tip and leading edges, to prevent damage by flying bits of sand, cinders, etc. Applied so as not to change size or shape of propeller in any way.

Torque, 33, 98, 168, 237
The reaction of the propeller upon the plane which has the effect of rolling the plane to the left, *i.e.*, opposite to the propeller direction of rotation.

Torque tubes, 124
A minor part of the control system by which the motion of the stick is transmitted to the aileron cables.

Tractor airplane,
An airplane of which the propeller is fastened in front of the wings, as in almost all modern land planes.

Triplane, 9
An airplane with three wing surfaces. It is not in common use, since its advantages are largely offset by its disadvantages.

Turn indicator, 139, 140, 141
An instrument for indicating any divergence to either side from a straight path.

Variation, 317, 323
Difference, measured in degrees, between true north (or geographic north pole) and the magnetic north (magnetic pole).

Venturi tube,
A tube, relatively short, and characterized by the fact that the middle section diameter is considerably less than either of the end diameters, with the result that as air flows through the tube the pressure at the constricted section is less than normal.

Washout, 56
A plane totally destroyed, or at least beyond repair.

Wheel, Deperdussin, 123
A wheel mounted on the top of the stick so that the rotation of the wheel operates the ailerons. In this case the stick cannot be moved sidewise, since the wheel replaces this motion, but the stick with the wheel on it is pulled back or pushed forward to operate the elevator as in the ordinary ship.

Whip stall,
A stall where the ship is in a vertical position and falls tail first till it attains speed and suddenly whips over head down.

Wind, relative,
The direction and velocity of the air with reference only to the plane.

No connection with ground speed or speed of air over ground.

Wind sock, 205
A cloth tube mounted in such a manner that it can swing with the wind and serve as an indicator of its direction and velocity.

Wind tunnel,
A tube through which a steady stream of air is blown, and within which models of airfoils or other bodies may be placed, to determine the forces resulting from the action of the air-stream upon the body.

Winds aloft, 107
Winds above the surface of the earth. They differ considerably in both velocity and direction.

Wires, "landing,"
Wires to prevent distortion of structure by overtightening "lift wires," by inverted flight, or by strains due to shock of landing or taxying.

Wires, "lift,"
Wires which transmit lift of wings to rest of structure.

Yaw, 99
When the plane has a tendency to turn to right or left it is called yawing.

Zoom,
A sudden, steep climb. A zoom is usually at an angle greater than that attainable in steady flight; hence lasts only a few seconds. Often used in stunts.

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